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(71)出願人　000226057
日亜化学工業株式会社
徳島県阿南市上中町岡491番地100

(72)発明者　松山　裕司
徳島県阿南市上中町岡491番地100　日亜化学工業株式会社内

(72)発明者　川田　康博
徳島県阿南市上中町岡491番地100　日亜化学工業株式会社内

(74)代理人　100074354
弁理士　豊栖　康弘　（外1名）

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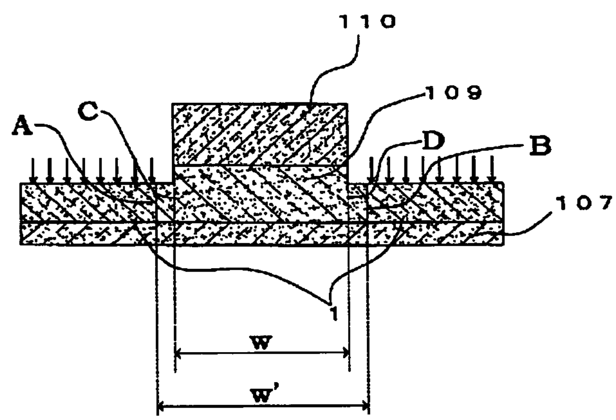
(54)【発明の名称】　窒化ガリウム系化合物半導体レーザ

(57)【要約】
【課題】　リッジ導波型ストライプ構造を有する窒化ガリウム系半導体化合物レーザおいて、遠視野像にリップルが現れるためにレーザスポットの集光に支障きたす。
【解決手段】　本発明の窒化ガリウム系半導体化合物レーザは、遠視野像におけるリップルの原因である水平横モードの広がりを制御するために、リッジの直下領域から離隔した位置に不純物原子を導入して形成される光吸収領域を有することを特徴とする。光吸収領域形成のために導入される不純物原子は、ＣｕやＣｒを除けばどのような原子でもよく、また導入した原子の熱拡散による移動を考慮して光吸収領域はリッジの直下領域から離れて形成されている必要がある。



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【特許請求の範囲】

【請求項１】　窒化ガリウム系化合物半導体から成る活性層をｐ型窒化ガリウム系化合物半導体層とｎ型窒化ガリウム系化合物半導体層とで挟んだ積層構造を有し、ｐ型窒化ガリウム系化合物半導体層が部分的に除去されてリッジが形成されている窒化ガリウム系化合物半導体レーザにおいて、

前記リッジ両側のｐ型窒化ガリウム系半導体層に、前記リッジの直下領域から離間して、Ｃｕ、Ｃｒを除く不純物原子を導入して成る光吸収領域が形成されていることを特徴とする窒化ガリウム系化合物半導体レーザ。

【請求項２】　前記不純物原子がＢ、Ａｌ、及びＮから成る群から選択された１種であることを特徴とする請求項１記載の窒化ガリウム系化合物半導体レーザ。

【請求項３】　前記光吸収領域が、リッジの直下部と０．５μｍ以上１０μｍ以下の距離で離間して形成されていることを特徴とする、請求項１記載の窒化ガリウム系化合物半導体レーザ。

【請求項４】　前記光吸収領域が、リッジの直下部と１μｍ以上５μｍ以下の距離で離間して形成されていることを特徴とする、請求項４記載の窒化ガリウム系化合物半導体レーザ。

【請求項５】　前記不純物原子が、イオン打ち込みによって導入されていることを特徴とする、請求項１記載の窒化ガリウム系化合物半導体レーザ。

【請求項６】　前記積層構造の深さ方向における前記不純物原子の濃度分布のピークが、活性層を含む光導波層内にあることを特徴とする、請求項６記載の窒化ガリウム系化合物半導体レーザ。

【請求項７】　前記光吸収領域の不純物原子の導入量が、1×10^{13}／ｃｍ^{2}以上1×10^{17}／ｃｍ^{2}以下であることを特徴とする、請求項１記載の窒化ガリウム系化合物半導体レーザ。

【請求項８】　前記光吸収領域の不純物原子の導入量が、1×10^{14}／ｃｍ^{2}以上1×10^{16}／ｃｍ^{2}以下であることを特徴とする、請求項８記載の窒化ガリウム系化合物半導体レーザ。

【発明の詳細な説明】

【０００１】

【発明の属する技術分野】本発明は窒化ガリウム系半導体化合物レーザに関する。

【０００２】

【従来の技術】今日、窒化物半導体を用いた半導体レーザは、ＤＶＤなど大容量・高密度の情報記録・再生が可能な光ディスクシステムへの利用に対する要求が高くなっている。特に、デジタル画像データを扱う次世代ＤＶＤには、波長の短かい青色レーザが必要不可欠と考えられている。青色半導体レーザとしては、窒化ガリウム系半導体化合物レーザが最も有力である。

【０００３】光ディスク、例えばＤＶＤのデータ読み取り・書き込みに用いるレーザスポットは、ピンポイントに集光されている必要があり、そのためには遠視野像（ファーフィールドパターン、ＦＦＰ）の中心位置が判明している必要がある。またＦＦＰの垂直方向、及び水平方向の強度分布は、ガウス分布となっているのが望ましい。この強度分布の状態を横モードといい、半導体レーザの構造によって制御することができる。

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【０００４】半導体レーザの代表的な構造は、活性層をｐ型及びｎ型クラッド層で挟み込んだダブルヘテロ接合構造（ＤＨ構造）である。ＤＨ構造は活性層へのキャリア閉じ込め効果、及び積層垂直方向の光の閉じ込め効果をねらったものである。ＤＨ構造の一種に、活性層とｐ型及びｎ型クラッド層との、おのおのの間に光ガイド層が形成されているＳＣＨ構造があり、この構成では、光は活性層及び光ガイド層の３層からなる光導波層に閉じ込められる。このようにして、ＳＣＨ構造により光の積層垂直方向の横モード（垂直横モード）を制御することができる。

【０００５】光の垂直横モードに加えて、さらに積層水平方向の横モード（水平横モード）も制御するために、ストライプ構造が用いられる。ストライプ構造は利得導波型ストライプ構造と屈折率導波型ストライプ構造とに大別される。なかにはリッジの直下領域とそれ以外の領域（リッジ外領域と呼称する）との実効的な屈折率の差により、光がリッジの直下領域に閉じ込められて光の水平横モードは制御されるリッジ導波型ストライプ構造がある。

【０００６】

【発明が解決しようとする課題】しかし、実際には前記リッジ導波型ストライプ構造における光閉じ込めは完全ではなく、リッジの直下領域からリッジ外領域へと微量の光が漏れ出している。リッジの直下領域から漏れ出した光（漏れ光）は発振するレーザ光と共に放出され、ＦＦＰではノイズ（リップル）として現れる。このＦＦＰのリップルによって、レーザスポットの集光に支障をきたし、ＤＶＤ等の光ディスクシステムの読み出し・書き込みエラーの一因となる。そこで本発明はリップルのないＦＦＰを示すレーザを得ることを目的とする。

【０００７】

【課題を解決するための手段】課題を解決するために、本発明は、窒化ガリウム系化合物半導体から成る活性層をｐ型窒化ガリウム系化合物半導体層とｎ型窒化ガリウム系化合物半導体層とで挟んだ積層構造を有し、ｐ型窒化ガリウム系化合物半導体層が部分的に除去されてリッジが形成されている窒化ガリウム系化合物半導体レーザにおいて、前記リッジ両側のｐ型窒化ガリウム系半導体層に、前記リッジの直下領域から離間して、Ｃｕ、Ｃｒを除く不純物原子を導入して成る光吸収領域が形成されていることを特徴とする。どのような不純物原子を導入しても光の吸収係数は上昇するので、導入する不純物原

子の種類は特に限定されないが、しかしＣｕやＣｒは発光層中のキャリア再結合領域に拡散すると、非発光再結合中心としてはたらき、発光強度が低下するので望ましくない。また、導入する不純物原子の、窒化ガリウム系化合物半導体中での拡散係数が大きい原子であると、やはり導入後にリッジの直下領域に移動して発光を阻害する可能性があるので、原子半径の小さい原子などの拡散係数の小さい原子を導入するのが好ましい。さらに好ましくは、移動度が低いＢ、Ａｌ、及びＮのうちのいずれかの不純物原子を導入して光吸収領域を形成する。

【０００８】本発明では、光吸収領域を形成する位置について、最低限２つの条件が挙げられる。光吸収領域を形成する位置の第一の条件は、リッジの直下領域を除くことである。リッジの直下領域は光の導波領域で、そこに吸収領域を形成することはレーザの発光効率を低下させる原因となる。次に、光吸収領域は、リッジの直下領域に接しないことが条件となる。不純物原子を導入した後、熱拡散によって不純物原子が拡散すると予測され、その結果として光吸収領域の拡大が起きても、リッジの直下領域には侵入しないようにするためである。

【０００９】また、光吸収領域をリッジの直下領域と接しない位置に形成するのは、次に述べる理由にもよる。リッジ導波型構造は、リッジの直下領域とリッジ外領域との実効的な屈折率が異なるという特徴を有し、その屈折率の境界面で光が反射することにより水平横モードを制御する。不純物原子の導入は、屈折率を変化させる効果もあることから、リッジ構造の屈折率境界面に不純物原子が侵入しないように注意しなくてはならない。従って、熱拡散による不純物原子の移動を考慮して、光吸収領域はリッジ両端から離れた位置に形成する必要がある。また漏れ光の吸収という機能が有効に働くためには、リッジと光吸収領域との距離が離れすぎてもよくない。原子の熱拡散と光吸収効果の兼ね合いから、適する離間距離は０．５～１０μｍとなり、さらに好ましくは１～５μｍである。

【００１０】本発明で、不純物原子の導入はどのような方法でもよいが、深さ方向の不純物原子導入位置の制御、不純物原子導入量の制御、及び量産性に優れているイオン打ち込みによって不純物原子を導入するのが好ましい。また漏れ光は光導波層に発生するので、深さ方向における不純物原子の濃度分布のピークが、光導波層に位置していることが望ましい。ここで光導波層とは、ｐ型及びｎ型クラッド層に挟まれている全ての層の集合を指し、これは主として光の閉じ込めが行われる層を意味する。ｐ型及びｎ型クラッド層の間には、例えば活性層の他に光ガイド層、電子閉じ込め層などが形成されていることもあり、それらの層は光導波層の一部とみなす。

【００１１】本発明で利用する光吸収領域では、不純物原子の密度を大きくすることによって吸収係数が増加する。しかし、導入量が多すぎると結晶格子自体が破壊されて、レーザ素子として機能しなくなる。結晶構造を保ちつつ、本発明の目的である漏れ光の吸収機能を実現するには、導入する不純物原子の量は1×10^{13}～1×10^{17}／cm^2の範囲にあればよく、好ましくは、1×10^{14}～1×10^{16}／cm^2である。

【００１２】

【発明の実施の形態】本発明の窒化ガリウム系化合物半導体レーザに用いる窒化ガリウム系化合物半導体としては、ＧａＮ、ＡｌＮ、もしくはＩｎＮ、又はこれらの混晶である窒化ガリウム系化合物半導体（$In_xAl_yGa_{1-x-y}N$、$0\leq x$、$0\leq y$、$x+y\leq1$）がある。その他に前記窒化ガリウム系化合物半導体の一部を、Ｂ、Ｐで置換した、混晶でもよい。

【００１３】図１は、本発明に係る窒化ガリウム系化合物半導体レーザの一例を示す断面図である。ＧａＮ基板１０１上において、$In_xGa_{1-x}N$（$0\leq x<1$）から成る活性層１０７が、ｎ型$Al_yGa_{1-y}N$（$0\leq y<1$）層１０３～１０６（各層毎にｙの値は異なる）と、ｐ型$Al_zGa_{1-z}N$（$0\leq z<1$）層１０８～１１１（各層毎にｚの値は異なる）によって挟まれており、いわゆるダブルヘテロ構造が形成されている。

【００１４】図２は、図１に示した半導体レーザの積層構造のうち、光吸収領域の形成に関する部分を抽出して図示したものである。光吸収領域１は、光ガイド層１０９、クラッド層１１０を順次積層し、次いでリッジストライプを形成した後に、むき出しになったｐ型光ガイド層の所定の位置に、不純物原子を導入して形成される。光吸収領域の開口幅ｗ’とリッジ幅ｗとの関係は、$w'\geq w+1\,\mu m$にすることが好ましい。また光吸収領域１を形成する位置は、光吸収領域の端面Ａとリッジの直下領域の端面Ｃ、及び光吸収領域の端面Ｂとリッジの直下領域の端面Ｄが、おのおの０．５～１０μｍだけ離れるようにし、さらに好ましくは、おのおの1～５μｍだけ離れるようにする。また、リッジを中心とした光吸収領域の２つの端面Ａ及びＢの位置関係は、左右対称になっているのが好ましいが、左右対称でなくてもよい。

【００１５】以下、図１に示す窒化ガリウム系化合物半導体レーザについて、構造の詳細について説明する。基板１０１としては、ＧａＮを用いることが好ましいが、窒化ガリウム系化合物半導体と異なる異種基板を用いても良い。異種基板としては、例えば、Ｃ面、Ｒ面、及びＡ面のいずれかを主面とするサファイア、スピネル（$MgAl_2O_4$のような絶縁性基板、ＳｉＣ（６Ｈ、４Ｈ、３Ｃを含む）、ＺｎＳ、ＺｎＯ、ＧａＡｓ、Ｓｉ、及び窒化ガリウム系化合物半導体と格子整合する酸化物基板等、窒化ガリウム系化合物半導体を成長させることが可能で従来から知られており、窒化ガリウム系化合物半導体と異なる基板材料を用いることができる。好ましい異種基板としては、サファイア、スピネルが挙げられる。また、異種基板は、オフアングルしていてもよく、この

場合ステップ状にオフアングルしたものを用いると窒化ガリウムからなる下地層が結晶性よく成長するため好ましい。更に、異種基板を用いる場合には、異種基板上にレーザ構造形成前の下地層となる窒化ガリウム系化合物半導体を成長させた後、異種基板を研磨などの方法により除去して、窒化ガリウム系化合物半導体の単体基板としてレーザ構造を形成してもよく、また、レーザ構造形成後に、異種基板を除去する方法でも良い。

【００１６】異種基板を用いる場合には、バッファ層（低温成長層）、窒化ガリウム系化合物半導体（好ましくはＧａＮ）からなる下地層を介して、レーザ構造を形成すると、窒化ガリウム系化合物半導体の成長が良好なものとなる。また、異種基板上に設ける下地層（成長基板）として、その他に、ELOG(Epitaxially Laterally Overgrowth)成長させた窒化ガリウム系化合物半導体を用いると結晶性が良好な成長基板が得られる。ELOG成長層の具体例としては、異種基板上に、窒化ガリウム系化合物半導体層を成長させ、その表面に窒化ガリウム系化合物半導体の成長が困難な保護膜を設けるなどして形成したマスク領域と、窒化ガリウム系化合物半導体を成長させる非マスク領域を、ストライプ状に設け、その非マスク領域から窒化ガリウム系化合物半導体を成長させることで、膜厚方向への成長に加えて、横方向への成長が成されることにより、マスク領域にも窒化ガリウム系化合物半導体が成長して成膜された層などがある。その他の形態では、異種基板上に成長させた窒化ガリウム系化合物半導体層に開口部を設け、その開口部側面から横方向への成長がなされて、成膜される層でもよい。

【００１７】基板１０１上には、バッファ層１０２を介して、ｎ型窒化ガリウム系化合物半導体層であるｎ型コンタクト層１０３、クラック防止層１０４、ｎ型クラッド層１０５、及びｎ型光ガイド層１０６が形成されている。ｎ型クラッド層１０５を除く他の層は、レーザによっては省略することもできる。ｎ型窒化ガリウム系化合物半導体層は、少なくとも活性層と接する部分において活性層よりも広いバンドギャップを有することが必要であり、そのためにＡｌを含む組成であることが好ましい。また、各層は、ｎ型不純物をドープしながら成長させてｎ型としても良いし、アンドープで成長させてｎ型としても良い。

【００１８】ｎ型窒化ガリウム系化合物半導体層１０３～１０６の上には、活性層１０７が形成されている。活性層１０７は、前述の通り、$In_{x_1}Ga_{1-x_1}N$井戸層（$0<x_1<1$）と$In_{x_2}Ga_{1-x_2}N$障壁層（$0\leq x_2<1$、$x_1>x_2$）が適当な回数だけ交互に繰り返し積層されたＭＱＷ構造を有しており、活性層の両端はいずれも障壁層となっている。井戸層は、アンドープで形成されており、全ての障壁層はＳｉ、Ｓｎ等のｎ型不純物が好ましくは$1\times10^{17}\sim1\times10^{19}/cm^3$の濃度でドープして形成されている。

【００１９】最終障壁層の上には、ｐ型窒化ガリウム系化合物半導体層として、ｐ型電子閉じ込め層１０８、ｐ型光ガイド層１０９、ｐ型クラッド層１１０、ｐ型コンタクト層１１１が形成されている。ｐ型クラッド層１１０を除く他の層は、レーザによっては省略することもできる。ｐ型窒化ガリウム系化合物半導体層は、少なくとも活性層と接する部分において活性層よりも広いバンドギャップを有することが必要であり、そのためにＡｌを含む組成であることが好ましい。また、各層は、ｐ型不純物をドープしながら成長させてｐ型としても良いし、隣接する他の層からｐ型不純物を拡散させてｐ型としても良い。

【００２０】ｐ型電子閉じ込め層１０８は、ｐ型クラッド層１１０よりも高いＡｌ混晶比を持つｐ型窒化ガリウム系化合物半導体から成り、好ましくは$Al_xGa_{1-x}N$（$0.1<x<0.5$）なる組成を有する。また、Ｍｇ等のｐ型不純物が高濃度で、好ましくは$5\times10^{17}\sim1\times10^{19}/cm^3$の濃度でドープされている。これにより、ｐ型電子閉じ込め層１０８は、電子を活性層中に有効に閉じ込めることができ、レーザの閾値を低下させる。

【００２１】ｐ型窒化ガリウム系化合物半導体層のうち、ｐ型光ガイド層１０９の途中までリッジストライプが形成され、さらに、保護膜１６１、１６２、ｐ型電極１２０、ｎ型電極１２１、ｐパット電極１２２、及びｎパット電極１２３が形成されて半導体レーザが構成されている。

【００２２】光吸収領域は、不純物原子の導入によって形成されるが、その方法としては、熱拡散やイオン打ち込みなどが挙げられる。しかし、熱拡散の場合には、窒化ガリウム化合物半導体の結晶が分解する温度（１０００℃程度）より低い温度で、光導波層に原子が拡散されなくてはならず、選択できる不純物原子が限定される。一方、イオン打ち込みで不純物原子を導入すると、どのような原子を用いたとしても半導体が１０００℃に達することはなく、不純物原子が自由に選択できる。

【００２３】イオン打ち込みの他の利点は、加速電圧を調節することで、不純物原子の導入深さを選択できることである。熱拡散を用いた場合、不純物原子の濃度分布は表面が最も高濃度で、深くなるに従って濃度が低くなる。しかし、イオン打ち込みを用いれば、結晶内部の所望の深さ位置に濃度ピークがくるような濃度分布の形成も可能である。本発明では、漏れ光が発生する光導波部層に不純物原子の濃度ピークがあることが望ましく、これはイオン打ち込みを用いれば実現可能である。

【００２４】導入する不純物原子は、その原子の窒化ガリウム半導体化合物結晶内における拡散係数によって選択される。一般的にレーザ発振中、素子は発熱し温度が上昇するが、光吸収領域に導入された原子は、濃度傾斜によって端面Ａ及びＢから拡散することになる。一般

に、１００℃程度の温度で熱拡散する拡散長は非常に微量ではあるが、原子半径が小さいなどの拡散係数の大きい原子はリッジ直下に拡散するおそれがあり、選択肢から除外した方が好ましい。また、Ｃｕ、Ｃｒ等は窒化物半導体発光デバイスではキラードーパントとして作用するため、これらの原子は除外する。導入する不純物原子としてはＡｌ、Ｂ、Ｎのいずれかを導入し、リッジとの距離を０．５～１０μｍの範囲に設定することでレーザ動作時の発熱に起因する拡散もほとんど生じず、またＧａＮ系発光デバイスでは非発光中心として作用しないので特に好ましい。

【００２５】不純物原子の導入量に依存して、物質の吸収係数は増加するため、漏れ光を完全に吸収させるには光吸収領域への原子導入量を増せばよい。しかし、不純物原子は半導体の結晶格子間に導入されるので、限度を超えた量を導入すると結晶の結合自体が破壊されて、素子として機能しなくなる。光の吸収と、結晶の保持の両方を満たす不純物原子の導入量は、1×10^{13}～$1\times10^{17}/cm^2$であり、さらに1×10^{14}～$1\times10^{16}/cm^2$が好ましい。

【００２６】［実施例１］以下、実施例として、図１に示すようなレーザ構造の窒化ガリウム系化合物半導体を用いたレーザで、さらに図２に示した光吸収領域を形成したものについて、説明する。

【００２７】（基板１０１）基板として、異種基板に成長させた窒化ガリウム系化合物半導体、本実施例ではＧａＮを厚膜（１００μｍ）で成長させた後、異種基板を除去して、８０μｍのＧａＮからなる窒化ガリウム系化合物半導体基板を用いる。基板の詳しい形成方法は、以下の通りである。２インチφ、Ｃ面を主面とするサファイアよりなる異種基板をＭＯＶＰＥ反応容器内にセットし、温度を５００℃にして、トリメチルガリウム（ＴＭＧ）、アンモニア（NH_3）を用い、ＧａＮよりなるバッファ層を２００Åの膜厚で成長させ、その後、温度を上げて、アンドープのＧａＮを１．５μｍの膜厚で成長させて、下地層とする。次に、下地層表面にストライプ状のマスクを複数形成して、マスク開口部（窓部）から窒化ガリウム系化合物半導体、本実施例ではＧａＮを選択成長させて、横方向の成長を伴った成長（ＥＬＯＧ）により成膜された窒化ガリウム系化合物半導体層を、さらに厚膜で成長させて、異種基板、バッファ層、下地層を除去して、窒化ガリウム系化合物半導体基板を得る。この時、選択成長時のマスクは、SiO_2からなり、マスク幅１５μｍ、開口部（窓部）幅５μｍとする。

【００２８】（バッファ層１０２）窒化ガリウム系化合物半導体基板の上に、バッファ層成長後、温度を１０５０℃にして、ＴＭＧ（トリメチルガリウム）、ＴＭＡ（トリメチルアルミニウム）、アンモニアを用い、$Al_{0.05}Ga_{0.95}N$よりなるバッファ層１０２を４μｍの膜厚で成長させる。この層は、ＡｌＧａＮのｎ型コンタクト層と、ＧａＮからなる窒化ガリウム系化合物半導体基板との間で、バッファ層として機能する。次に、窒化ガリウム系化合物半導体からなる下地層の上に、レーザ構造となる各層を積層する。

【００２９】（ｎ型コンタクト層１０３）次に得られたバッファ層１０２上にＴＭＧ、ＴＭＡ、アンモニア、不純物ガスとしてシランガスを用い、１０５０℃でＳｉドープした$Al_{0.05}Ga_{0.95}N$よりなるｎ型コンタクト層１０３を４μｍの膜厚で成長させる。

【００３０】（クラック防止層１０４）次に、ＴＭＧ、ＴＭＩ（トリメチルインジウム）、アンモニアを用い、温度を８００℃にして$In_{0.06}Ga_{0.94}N$よりなるクラック防止層１０４を０．１５μｍの膜厚で成長させる。なお、このクラック防止層は省略可能である。

【００３１】（ｎ型クラッド層１０５）次に、温度を１０５０℃にして、原料ガスにＴＭＡ、ＴＭＧ及びアンモニアを用い、アンドープの$Al_{0.05}Ga_{0.95}N$よりなるＡ層を２５Åの膜厚で成長させ、続いて、ＴＭＡを止め、不純物ガスとしてシランガスを用い、Ｓｉを$5\times10^{18}/cm^3$ドープしたＧａＮよりなるＢ層を２５Åの膜厚で成長させる。そして、この操作をそれぞれ２００回繰り返してＡ層とＢ層の積層し、総膜厚１μｍの多層膜（超格子構造）よりなるｎ型クラッド層１０６を成長させる。この時、アンドープＡｌＧａＮのＡｌ混晶比としては、０．０５以上０．３以下の範囲であれば、十分にクラッド層として機能する屈折率差を設けることができる。

【００３２】（ｎ型光ガイド層１０６）次に、同様の温度で、原料ガスにＴＭＧ及びアンモニアを用い、アンドープのＧａＮよりなるｎ型光ガイド層１０６を０．１５μｍの膜厚で成長させる。また、ｎ型不純物をドープしてもよい。

【００３３】（活性層１０７）次に、温度を８００℃にして、原料ガスにＴＭＩ（トリメチルインジウム）、ＴＭＧ及びアンモニアを用い、不純物ガスとしてシランガスを用い、Ｓｉを$5\times10^{18}/cm^3$ドープした$In_{0.05}Ga_{0.95}N$よりなる障壁層（Ｂ）を１４０Åの膜厚で、シランガスを止め、アンドープの$In_{0.1}Ga_{0.9}N$よりなる井戸層（Ｗ）を５５Åの膜厚で、この障壁層（Ｂ）、井戸層（Ｗ）を、（Ｂ）／（Ｗ）／（Ｂ）／（Ｗ）の順に積層する。活性層１０７は、総膜厚約５００Åの多重量子井戸構造（ＭＱＷ）となる。

【００３４】（ｐ型電子閉込め層１０８）次に、同様の温度で、原料ガスにＴＭＡ、ＴＭＧ及びアンモニアを用い、不純物ガスとしてCp_2Mg（シクロペンタジエニルマグネシウム）を用い、Ｍｇを$1\times10^{19}/cm^3$ドープした$Al_{0.3}Ga_{0.7}N$よりなるｐ型電子閉込層１０８を１００Åの膜厚で成長させる。この層は、特に設けられていなくても良いが、設けることで電子閉込めとして機能し、閾値の低下に寄与するものとなる。

【００３５】（ｐ型光ガイド層１０９）次に、温度を１０５０℃にして、原料ガスにＴＭＧ及びアンモニアを用い、アンドープのＧａＮよりなるｐ型光ガイド層１０９を０．１５μｍの膜厚で成長させる。このｐ型光ガイド層１０９は、アンドープとして成長させるが、ｐ型電子閉込め層１０８、ｐ型クラッド層１０９等の隣接層からのＭｇの拡散により、Ｍｇ濃度が$5×10^{16}$／cm^3となりｐ型を示す。またこの層は成長時に意図的にＭｇをドープしても良い。

【００３６】（ｐ型クラッド層１１０）続いて、１０５０℃でアンドープ$Al_{0.05}Ga_{0.95}N$よりなる層を２５Åの膜厚で成長させ、続いてＴＭＡを止め、Cp_2Mgを用いて、ＭｇドープＧａＮよりなる層を２５Åの膜厚で成長させ、それを９０回繰り返して総膜厚０．４５μｍの超格子層よりなるｐ型クラッド層１１０を成長させる。ｐ型クラッド層は少なくとも一方がＡｌを含む窒化ガリウム系化合物半導体層を含み、互いにバンドギャップエネルギーが異なる窒化ガリウム系化合物半導体層を積層した超格子で作製した場合、不純物はいずれか一方の層に多くドープして、いわゆる変調ドープを行うと結晶性が良くなる傾向にあるが、両方に同じようにドープしても良い。クラッド層１１０は、Ａｌを含む窒化ガリウム系化合物半導体層、好ましくは$Al_XGa_{1-X}N$（$0<X<1$）を含む超格子構造とすることが望ましく、さらに好ましくはＧａＮとＡｌＧａＮとを積層した超格子構造とする。ｐ側クラッド層１１０を超格子構造とすることによって、クラッド層全体のＡｌ混晶比を上げることができるので、クラッド層自体の屈折率が小さくなり、さらにバンドギャップエネルギーが大きくなるので、閾値を低下させる上で非常に有効である。さらに、超格子としたことにより、クラッド層自体に発生するピットが超格子にしないものよりも少なくなるので、ショートの発生も低くなる。

【００３７】（ｐ型コンタクト層１１１）最後に、１０５０℃で、ｐ型クラッド層１１０の上に、Ｍｇを$1×10^{20}$／cm^3ドープしたｐ型ＧａＮよりなるｐ型コンタクト層１１１を１５０Åの膜厚で成長させる。ｐ型コンタクト層１１１はｐ型の$In_XAl_YGa_{1-X-Y}N$（$0≦X$、$0≦Y$、$X+Y≦1$）で構成することができ、好ましくはＭｇをドープしたＧａＮとすれば、ｐ電極１２０と最も好ましいオーミック接触が得られる。コンタクト層１１１は電極を形成する層であるので、$1×10^{17}$／cm^3以上の高キャリア濃度とすることが望ましい。$1×10^{17}$／cm^3よりも低いと電極と好ましいオーミックを得るのが難しくなる傾向にある。さらにコンタクト層の組成をＧａＮとすると、電極材料と好ましいオーミックが得られやすくなる。反応終了後、反応容器内において、ウエハを窒素雰囲気中、７００℃でアニーリングを行い、ｐ型層を更に低抵抗化する。

【００３８】以上のようにして窒化ガリウム系化合物半導体を成長させ各層を積層した後、ウエハを反応容器から取り出し、最上層のｐ型コンタクト層の表面にSiO_2よりなる保護膜を形成して、ＲＩＥ（反応性イオンエッチング）を用い$SiCl_4$ガスによりエッチングし、図１に示すように、ｎ電極を形成すべきｎ型コンタクト層１０３の表面を露出させる。このように窒化ガリウム系化合物半導体を深くエッチングするには保護膜としてSiO_2が最適である。

【００３９】次に上述したストライプ状の導波路領域として、リッジストライプを形成する。まず、最上層のｐ型コンタクト層（上部コンタクト層）のほぼ全面に、ＰＶＤ装置により、Ｓｉ酸化物（主として、SiO_2）よりなる第１の保護膜１６１を０．５μｍの膜厚で形成した後、第１の保護膜１６１の上に所定の形状のマスクをかけ、ＲＩＥ（反応性イオンエッチング）装置により、CF_4ガスを用い、フォトリソグラフィー技術によりストライプ幅１．６μｍの第１の保護膜１６１とする。この時、リッジストライプの高さ（エッチング深さ）は、ｐ型コンタクト層１１１、およびｐ型クラッド層１０９、ｐ型光ガイド層１１０の一部をエッチングして、ｐ型光ガイド層１０９の膜厚が０．１μｍとなる深さまでエッチングして、形成する。

【００４０】（光吸収領域）リッジストライプの上面、側面、及びリッジ側面に連続する平面（ｐ型光ガイド層１０９の露出面）のうちリッジ側面から１μｍまでの範囲（図２に示したｐ型クラッド層１１０、ｐ型光ガイド層１０９の表面部分に相当）に、レジストのマスクを形成する。次に、イオン打ち込み装置にてホウ素イオンを導入し、図２に示した光吸収領域１を形成する。イオン打ち込み条件は、加速電圧３０ｋｅＶで６分間、ホウ素イオンの導入量（ドーズ量）は$1×10^{15}$／cm^2とする。

【００４１】次に、第１の保護膜１６１の上から、Ｚｒ酸化物（主としてZrO_2）よりなる第２の保護膜１６２を、第１の保護膜１６１の上と、エッチングにより露出されたｐ型光ガイド層１０９の上に０．５μｍの膜厚で連続して形成する。

【００４２】第２の保護膜１６２形成後、ウエハを６００℃で熱処理する。このようにSiO_2以外の材料を第２の保護膜として形成した場合、第２の保護膜成膜後に、３００℃以上、好ましくは４００℃以上、窒化ガリウム系化合物半導体の分解温度以下（１２００℃）で熱処理することにより、第２の保護膜が第１の保護膜の溶解材料（フッ酸）に対して溶解しにくくなるため、この工程を加えることがさらに望ましい。

【００４３】次に、ウエハをフッ酸に浸漬し、第１の保護膜１６１をリフトオフ法により除去する。このことにより、ｐ型コンタクト層１１１の上に設けられていた第１の保護膜１６１が除去されて、ｐ型コンタクト層が露出される。以上のようにして、図１に示すように、リッ

ジストライプの側面、及びそれに連続する平面（ｐ型光ガイド層１０９の露出面）に第２の保護膜１６２が形成される。

【００４４】このように、ｐ型コンタクト層１１２の上に設けられた第１の保護膜１６１が、除去された後、図１に示すように、その露出したｐ型コンタクト層１１１の表面にＮｉ／Ａｕよりなるｐ電極１２０を形成する。但しｐ電極１２０は１００μｍのストライプ幅として、図１に示すように、第２の保護膜１６２の上に渡って形成する。第２の保護膜１６２形成後、既に露出させたｎ型コンタクト層１０３の表面にはＴｉ／Ａｌよりなるストライプ状のｎ電極１２１をストライプと平行な方向で形成する。

【００４５】次に、ｎ電極を形成するためにエッチングして露出された面でｐ，ｎ電極に、取り出し電極を設けるため所望の領域にマスクし、SiO_2とTiO_2よりなる誘電体多層膜１６４を設けた後、ｐ，ｎ電極上にＮｉ－Ｔｉ－Ａｕ（１０００Å－１０００Å－８０００Å）よりなる取り出し（パット）電極１２２，１２３をそれぞれ設けた。この時、活性層１０７の幅は、２００μｍの幅（共振器方向に垂直な方向の幅）であり、共振器面（反射面側）にもSiO_2とTiO_2よりなる誘電体多層膜が設けられる。

【００４６】以上のようにして、ｎ電極とｐ電極とを形成した後、ストライプ状の電極に垂直な方向で、窒化ガリウム系化合物半導体のＭ面（ＧａＮのＭ面、（１１-００）など）でバー状に分割して、更にバー状のウエハを分割してレーザを得る。この時、共振器長は、６５０μｍである。

【００４７】このレーザ素子をヒートシンクに設置し、それぞれのパッド電極をワイヤーボンディングして室温でレーザ発振を試みたところ、発振波長４００～４２０ｎｍ、発振閾値電流密度２．９ｋＡ／cm^2において単一横モードでの室温連続発振を示した。またＦＦＰを測定したところ、水平方向の光強度分布は図３のようになり、リップルの発生が大幅に抑制されてなめらかな強度分布であった。強度のピーク位置も、ＦＦＰの中心位置にほぼ一致した。

【００４８】［実施例２］実施例１における不純物原子（ホウ素）の導入量を、1×10^{14}／cm^2に変更して光吸収領域を形成した窒化ガリウム系半導体化合物レーザを作成し、実施例１と同条件で発振を行った。ＦＦＰを測定したところ、水平方向の光強度分布は図４のように若干のリップルが現れているが、比較例（図６）と比べるとリップルが大幅に制限されていることがわかる。

【００４９】［実施例３］実施例１における不純物原子（ホウ素）の導入量を、1×10^{16}／cm^2に変更して光吸収領域を形成した窒化ガリウム系半導体化合物レーザを作成し、実施例１と同様の条件で発振を行った。ＦＦＰを測定したところ、水平方向の光強度分布は図５のように若干のリップルが現れているが、比較例（図６）と比べるとリップルが大幅に制限されていることがわかる。

【００５０】［比較例］実施例１乃至３における、光吸収領域の形成過程を除いて光吸収領域のない窒化ガリウム系半導体化合物レーザを作成し、実施例１と同様の条件で発振を行った。ＦＦＰを測定したところ、水平方向の光強度分布は図６のようであり、リップルが大量に発生していることが確認された。図３乃至５と比較すると、光強度分布の形状がなめらかでなく、またピーク位置は本来のＦＦＰのピーク位置からずれていることが判った。

【００５１】

【発明の効果】本発明の窒化ガリウム系化合物半導体レーザは、光導波層の一部に光吸収領域を有する構造を有することにより、リッジ導波型ストライプ構造の欠点である水平横モード制御が強化されている。その結果、従来の窒化ガリウム系化合物半導体レーザに現れていたＦＦＰのリップルが効率よく消去された。その結果、ＦＦＰの水平方向の強度分布は、リップルの除去によりなめらかになり、またそのピーク位置はＦＦＰの中心に一致するようになり、これによってレーザスポットを精度よく集光することが可能となる。

【図面の簡単な説明】

【図１】　本発明の実施形態を説明する半導体レーザの模式断面図である。

【図２】　本発明の実施形態のうち、光吸収領域及びその周辺の構成を抽出した図である。

【図３】　実施例１のレーザのＦＦＰの、水平方向における強度分布である。

【図４】　実施例２のレーザのＦＦＰの、水平方向における強度分布である。

【図５】　実施例３のレーザのＦＦＰの、水平方向における強度分布である。

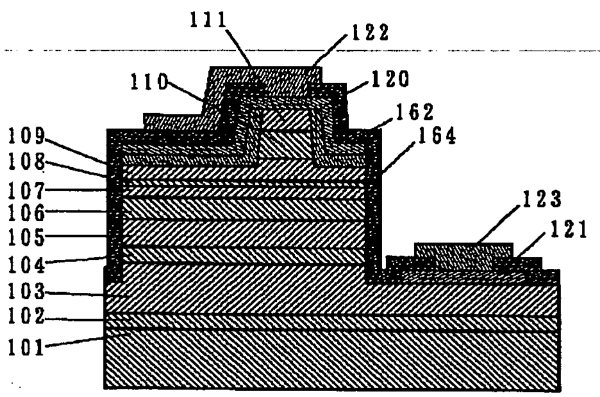
【図６】　比較例のレーザのＦＦＰの、水平方向における強度分布である。

【符号の簡単な説明】

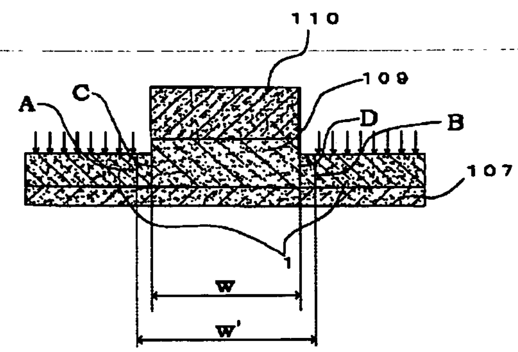
１・・・光吸収層
ｗ・・・リッジ幅
ｗ’・・・光吸収領域の開口幅
Ａ・・・光吸収領域の端面
Ｂ・・・光吸収領域の端面
Ｃ・・・リッジの直下領域の端面
Ｄ・・・リッジの直下領域の端面
１０１・・・基板（ＧａＮ基板）
１０２・・・バッファ層
１０３・・・ｎ型コンタクト層
１０４・・・クラック防止層
１０５・・・ｎ型クラッド層

１０６・・・ｎ型光ガイド層
１０７・・・活性層
１０８・・・ｐ型電子閉込め層
１０９・・・ｐ型光ガイド層
１１０・・・ｐ型クラッド層
１１１・・・ｐ型コンタクト層
＊１２０・・・ｐ電極
１２１・・・ｎ電極
１２２・・・ｐパッド電極
１２３・・・ｎパッド電極
１６３・・・第３の保護膜
＊ １６４・・・絶縁膜

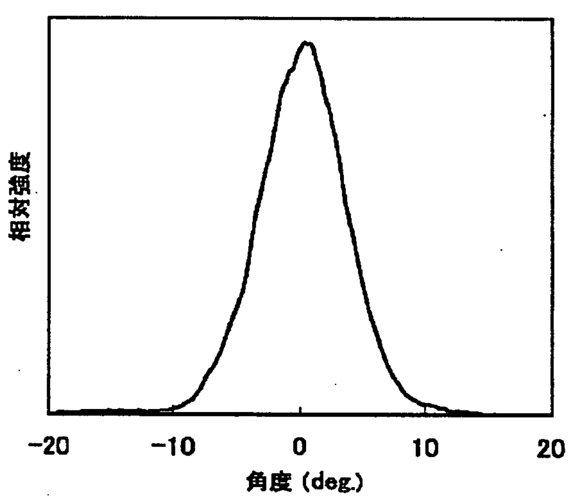
【図１】



【図２】



【図３】



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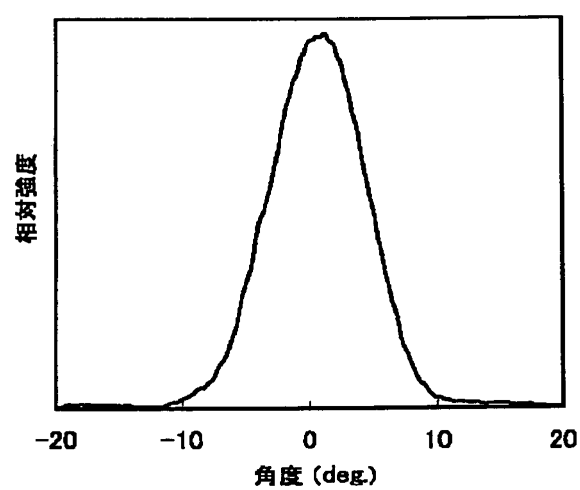
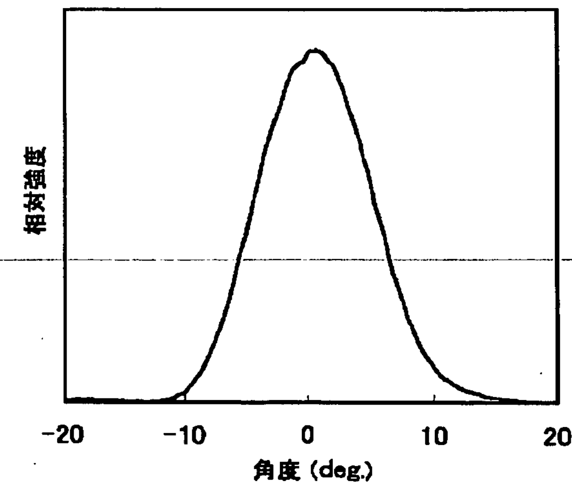
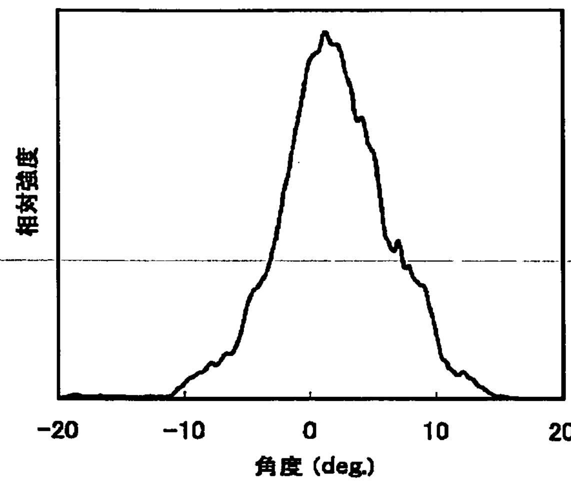


【図５】



【図６】



フロントページの続き

Ｆターム(参考)　5F073 AA13 AA45 AA51 AA74 BA04
　　　　　　　　　　CA07 CB02 CB07 CB19 CB22
　　　　　　　　　　DA05 DA14 DA25 EA18

CLAIMS

[Claim(s)]
[Claim 1] It has the laminated structure which sandwiched the barrier layer which consists of a gallium nitride system compound semiconductor in p mold gallium nitride system compound semiconductor layer and n mold gallium nitride system compound semiconductor layer. In the gallium nitride system compound semiconductor laser with which p mold gallium nitride system compound semiconductor layer is partially removed, and the ridge is formed Gallium nitride system compound semiconductor laser characterized by forming the light absorption field which estranges in p mold gallium nitride system semi-conductor layer of said ridge both sides from the directly under field of said ridge, introduces the impurity atom except Cu and Cr into it, and grows into it.
[Claim 2] Gallium nitride system compound semiconductor laser according to claim 1 characterized by being one sort chosen from the group to which said impurity atom changes from B, aluminum, and N.
[Claim 3] Gallium nitride system compound semiconductor laser according to claim 1 characterized by for said light absorption field estranging and forming it in the direct lower part of a ridge, and 0.5-micrometer or more distance of 10 micrometers or less.
[Claim 4] Gallium nitride system compound semiconductor laser according to claim 4 characterized by for said light absorption field estranging and forming it in the direct lower part of a ridge, and 1-micrometer or more distance of 5 micrometers or less.
[Claim 5] Gallium nitride system compound semiconductor laser according to claim 1 with which said impurity atom is characterized by being introduced by ion implantation.
[Claim 6] Gallium nitride system compound semiconductor laser according to claim 6 characterized by the peak of concentration distribution of said impurity atom in the depth direction of said laminated structure being in the lightguide containing a barrier layer.
[Claim 7] Gallium nitride system compound semiconductor laser according to claim 1 with which the amount of installation of the impurity atom of said light absorption field is characterized by being two or less two or more 1x1013-/cm1x1017-/cm.
[Claim 8] Gallium nitride system compound semiconductor laser according to claim 8 with which the amount of installation of the impurity atom of said light absorption

field is characterized by being two or less two or more 1x1014-/cm1x1016-/cm.

[Translation done.]

DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Field of the Invention] This invention relates to gallium nitride system semiconducting compound laser.
[0002]
[Description of the Prior Art] The demand to use to the optical disc system which the semiconductor laser using a nitride semi-conductor can reproduce [information record and] is high today. [of large capacity, such as DVD, and high density] It is considered by especially the next generation DVD treating digital image data for the short paddle blue laser of wavelength to be indispensable. As blue semiconductor laser, gallium nitride system semiconducting compound laser is the most leading.
[0003] The laser spot used for data reading and the writing of an optical disk, for example, DVD, needs to be condensed by pinpoint, and, for that purpose, the center position of a far field pattern (a far field pattern, FFP) needs to become clear. Moreover, as for the perpendicular direction of FFP, and horizontal intensity distribution, it is desirable that it is Gaussian distribution. The condition of these intensity distribution can be called transverse mode, and it can control by structure of semiconductor laser.
[0004] The typical structure of semiconductor laser is the double heterojunction structure (DH structure) which put the barrier layer by p mold and n mold cladding layer. DH structure aims at the carrier locked-in effect to a barrier layer, and the locked-in effect of the light of a laminating perpendicular direction. The SCH structure where the lightguide layer is formed between [each] the barrier layer, p mold, and n mold cladding layer is in a kind of DH structure, and light is confined in the lightguide which consists of three layers of a barrier layer and a lightguide layer with this configuration. Thus, the transverse mode (perpendicular transverse mode) of the laminating perpendicular direction of light is controllable by SCH structure.
[0005] Stripe geometry is used in order to also control the transverse mode (level transverse mode) of a laminating horizontal direction further in addition to the perpendicular transverse mode of light. Stripe geometry is divided roughly into gain guided wave mold stripe geometry and refractive-index guided wave mold stripe geometry. Light is confined in the directly under field of a ridge by the difference of the effectual refractive index of the directly under field of a ridge, and the other

field (the field outside a ridge is called) in inside, and the level transverse mode of light has the ridge guided wave mold stripe geometry controlled.

[0006]

[Problem(s) to be Solved by the Invention] However, in fact, the optical confinement in said ridge guided wave mold stripe geometry is not perfect, and the light of a minute amount is beginning to leak from the directly under field of a ridge to the field outside a ridge. The light (leakage light) which began to leak from the directly under field of a ridge is emitted with the laser beam to oscillate, and appears as a noise (ripple) in FFP. By this ripple of FFP, trouble is caused to condensing of a laser spot and it becomes the cause of the read-out and the write error of optical disc systems, such as DVD. Then, this invention aims at obtaining the laser in which FFP without a ripple is shown.

[0007]

[Means for Solving the Problem] In order to solve a technical problem, this invention has the laminated structure which sandwiched the barrier layer which consists of a gallium nitride system compound semiconductor in p mold gallium nitride system compound semiconductor layer and n mold gallium nitride system compound semiconductor layer. In the gallium nitride system compound semiconductor laser with which p mold gallium nitride system compound semiconductor layer is partially removed, and the ridge is formed It is characterized by forming the light absorption field which estranges in p mold gallium nitride system semi-conductor layer of said ridge both sides from the directly under field of said ridge, introduces the impurity atom except Cu and Cr into it, and grows into it. No matter what atom [impurity] it may introduce, since an absorption-of-light multiplier rises, especially the class of impurity atom to introduce is not limited, but if spread to the carrier recombination field in a luminous layer, since ****** and luminescence reinforcement will fall as a nonluminescent recombination center, neither Cu nor Cr is desirable. Moreover, since the diffusion coefficient in the inside of the gallium nitride system compound semiconductor of the impurity atom to introduce may move too that it is a large atom to the directly under field of a ridge after installation and may check luminescence, it is desirable to introduce an atom with the small diffusion coefficient of the small atom of an atomic radius etc. Still more preferably, mobility introduces the impurity atom of either of low B, aluminum, and N, and forms a light absorption field.

[0008] In this invention, two conditions are mentioned at worst about the location which forms a light absorption field. The first condition of the location which forms a light absorption field is removing the directly under field of a ridge. The directly under field of a ridge is a guided wave field of light, and forming an absorption field there becomes the cause of reducing the luminous efficiency of laser. Next, it becomes conditions that a light absorption field does not touch the directly under field of a ridge. After introducing an impurity atom, even if it is predicted by thermal diffusion that an impurity atom is spread and expansion of a light absorption field breaks out as the result by it, it is for making it not trespass upon the directly under field of a ridge.

[0009] Moreover, forming a light absorption field in the location which does not

touch the directly under field of a ridge is based also on the reason explained below. Ridge guided wave mold structure has the description that the effectual refractive indexes of the directly under field of a ridge and the field outside a ridge differ, and when light reflects in the interface of the refractive index, it controls the level transverse mode. Installation of an impurity atom must be careful also of the effectiveness of changing a refractive index for an impurity atom not to trespass upon the refractive-index interface of ridge structure from a certain thing. Therefore, in consideration of migration of the impurity atom by thermal diffusion, it is necessary to form a light absorption field in the location distant from ridge both ends. Moreover, in order for the function of the leakage absorption of light to work effectively, the distance of a ridge and a light absorption field must not separate too much. The clearance for which are suitable is set to 0.5-10 micrometers from atomic thermal diffusion and the balance of the light absorption effectiveness, and it is 1-5 micrometers still more preferably.

[0010] It is desirable to introduce an impurity atom by the ion implantation which is excellent in this invention at control of the impurity atom installation location of the depth direction, control of the amount of impurity atom installation, and mass-production nature although what kind of approach may be used for installation of an impurity atom. Moreover, since it generates in a lightguide, as for leakage light, it is desirable to locate the peak of concentration distribution of the impurity atom in the depth direction in a lightguide. A lightguide points out the set of all the layers pinched by p mold and n mold cladding layer, and this means the layer in which light mainly closes and eye ** is performed here. Between p mold and n mold cladding layer, since the lightguide layer, the electronic confining layer, etc. are formed other than the barrier layer, it is considered that those layers are a part of lightguides.

[0011] In the light absorption field used by this invention, an absorption coefficient increases by enlarging the consistency of an impurity atom. When there are too many amounts of installation, the crystal lattice itself is destroyed and it stops however, functioning as a laser component. In order to realize the leakage absorption-of-light function which is the purpose of this invention, maintaining the crystal structure, the amount of the impurity atom to introduce is 1x1014 to 1x1016-/cm2 preferably that what is necessary is just to be in the range of 1x1013 to 1x1017-/cm2.

[0012]

[Embodiment of the Invention] As a gallium nitride system compound semiconductor used for the gallium nitride system compound semiconductor laser of this invention, there is a gallium nitride system compound semiconductor (InxAlyGa1-x-yN, 0<=x, 0<=y, x+y<=1) which are GaN, AlN, InN(s), or such mixed crystal. In addition, the mixed crystal which permuted said some of gallium nitride system compound semiconductors by B and P is sufficient.

[0013] Drawing 1 is the sectional view showing an example of the gallium nitride system compound semiconductor laser concerning this invention. The barrier layer 107 which consists of InxGa1-xN (0<=x<1) on the GaN substrate 101 is sandwiched by the n mold AlyGa1-yN (0<=y<1) layers 103-106 (the values of y differ for each class), and the p mold AlzGa1-zN (0<=z<1) layers 108-111 (the

values of z differ for each class), and terrorism structure is formed in the so-called double.

[0014] Drawing 2 extracts and illustrates the part about formation of a light absorption field among the laminated structures of the semiconductor laser shown in drawing 1 . After the light absorption field 1 carries out the laminating of the lightguide layer 109 and the cladding layer 110 one by one and subsequently forms a ridge stripe, it introduces an impurity atom into the position of p mold lightguide layer which became unreserved, and is formed in it. As for aperture-width w' of a light absorption field, and the relation with the ridge width of face w, it is desirable to make it w'>=w+1micrometer. Moreover, the end face A of a light absorption field, the end face C of the directly under field of a ridge, and the end face B of a light absorption field and the end face D of the directly under field of a ridge leave respectively only 0.5-10 micrometers of locations which form the light absorption field 1, and leaves them only 1-5 micrometers respectively still more preferably. Moreover, although it is desirable that it is bilateral symmetry as for the physical relationship of two end faces A and B of the light absorption field centering on a ridge, it may not be bilateral symmetry.

[0015] Hereafter, the detail of structure is explained about the gallium nitride system compound semiconductor laser shown in drawing 1 . Although it is desirable as a substrate 101 to use GaN, a different different-species substrate from a gallium nitride system compound semiconductor may be used. The sapphire which makes a principal plane either C side, the Rth page and the Ath page as a different-species substrate, for example, Spinel (an insulating substrate like MgA 12O4, SiC (4H 6H)) ZnS, ZnO, GaAs and Si containing 3C, the oxide substrate which carries out lattice matching to a gallium nitride system compound semiconductor can grow up a gallium nitride system compound semiconductor, and is known from the former, and a different substrate ingredient from a gallium nitride system compound semiconductor can be used. Sapphire and a spinel are mentioned as a desirable different-species substrate. Moreover, a different-species substrate is desirable in order that the substrate layer which consists of gallium nitride may grow with sufficient crystallinity, if what may be carrying out the off angle type and carried out the off angle type to the shape of a step in this case is used. Furthermore, the approach of removing a different-species substrate by approaches, such as polish, forming laser structure as a simple substance substrate of a gallium nitride system compound semiconductor after growing up the gallium nitride system compound semiconductor used as the substrate layer before laser structure formation on a different-species substrate, in using a different-species substrate, and removing a different-species substrate after laser structure formation may be used.

[0016] If it forms laser structure through a buffer layer (low-temperature growth phase) and the substrate layer which consists of a gallium nitride system compound semiconductor (preferably GaN) in using a different-species substrate, growth of a gallium nitride system compound semiconductor will become good. Moreover, if the gallium nitride system compound semiconductor which used as the substrate layer (growth substrate) prepared on a different-species substrate, in addition carried out ELOG (Epitaxially Laterally Overgrowth) growth is used, a

growth substrate with good crystallinity will be obtained. The mask field where the gallium nitride system compound semiconductor layer was grown up, and growth of a gallium nitride system compound semiconductor prepared and formed the difficult protective coat on the front face on the different-species substrate as an example of an ELOG growth phase, By preparing the non-mask field into which a gallium nitride system compound semiconductor is grown up in the shape of a stripe, and growing up a gallium nitride system compound semiconductor from the non-mask field In addition to growth in the direction of thickness, when growth in a longitudinal direction accomplishes, there is a layer in which the gallium nitride system compound semiconductor grew up to be also a mask field, and was formed. The layer which opening is prepared in the gallium nitride system compound semiconductor layer grown up on the different-species substrate with other gestalten, and the growth in a longitudinal direction from the opening side face is made, and is formed is sufficient.
[0017] On the substrate 101, n mold contact layer 103 which is n mold gallium nitride system compound semiconductor layer, the crack prevention layer 104, n mold cladding layer 105, and n mold lightguide layer 106 are formed through the buffer layer 102. Other layers except n mold cladding layer 105 are also omissible depending on laser. n mold gallium nitride system compound semiconductor layer needs to have a band gap larger than a barrier layer in the part which touches a barrier layer at least, therefore it is desirable that it is the presentation containing aluminum. Moreover, it is made to grow up, doping n mold impurity, and is good also as an n mold, and each class is grown up by undoping and is good also as an n mold.
[0018] The barrier layer 107 is formed on n mold gallium nitride system compound semiconductor layers 103-106. The barrier layer 107 has the MQW structure where the laminating only of the count with suitable Inx1Ga1-x2N well layer (0<x1<1) and Inx2Ga1-x2N barrier layer (0 <=x2<1, x1> x2) was carried out repeatedly by turns, as above-mentioned, and each both ends of a barrier layer serve as a barrier layer. The well layer is formed by undoping, n mold impurities, such as Si and Sn, dope all barrier layers preferably by the concentration of 1x1017 to 1x1019-/cm3, and they are formed.
[0019] On the last barrier layer, p mold electronic confining layer 108, p mold lightguide layer 109, p mold cladding layer 110, and p mold contact layer 111 are formed as a p mold gallium nitride system compound semiconductor layer. Other layers except p mold cladding layer 110 are also omissible depending on laser. p mold gallium nitride system compound semiconductor layer needs to have a band gap larger than a barrier layer in the part which touches a barrier layer at least, therefore it is desirable that it is the presentation containing aluminum. Moreover, it is made to grow up, doping p mold impurity, and is good also as a p mold, and each class diffuses p mold impurity from other adjoining layers, and is good also as a p mold.
[0020] from p mold gallium nitride system compound semiconductor in which p mold electronic confining layer 108 has aluminum mixed-crystal ratio higher than p mold cladding layer 110 -- changing -- desirable -- AlxGa1-xN (0.1< x<0.5) -- it has a presentation. Moreover, p mold impurities, such as Mg, are preferably doped

by high concentration by the concentration of 5x1017 to 1x1019-/cm3. Thereby, p mold electronic confining layer 108 can shut up an electron effectively in a barrier layer, and reduces the threshold of laser.
[0021] A ridge stripe is formed to the middle of p mold lightguide layer 109 among p mold gallium nitride system compound semiconductor layers, further, protective coats 161 and 162, p mold electrode 120, n mold electrode 121, p putt electrode 122, and n putt electrode 123 are formed, and semiconductor laser is constituted.
[0022] Although a light absorption field is formed of installation of an impurity atom, thermal diffusion, ion implantation, etc. are mentioned as the approach. However, in the case of thermal diffusion, at temperature lower than the temperature (about 1000 degrees C) which the crystal of a nitriding gallium compound semi-conductor decomposes, an atom must be spread in a lightguide and the impurity atom which can be chosen is limited. On the other hand, if an impurity atom is introduced by ion implantation, even if it uses what kind of atom, a semi-conductor does not amount to 1000 degrees C, and an impurity atom can choose freely.
[0023] Other advantages of ion implantation are adjusting acceleration voltage, and are being able to choose the introductory depth of an impurity atom. When thermal diffusion is used, concentration becomes low as concentration distribution of an impurity atom is high concentration most and a front face becomes deep. However, if ion implantation is used, formation of concentration distribution for which a concentration peak comes to the depth location of the request inside a crystal is also possible. In this invention, if it is desirable for the concentration peak of an impurity atom to be in the photoconductive wave member which leakage light generates and this uses ion implantation, it is realizable.
[0024] The impurity atom to introduce is chosen by the diffusion coefficient in the gallium nitride semiconducting compound crystal of the atom. Generally, among laser oscillation, although a component generates heat and temperature rises, the atom introduced into the light absorption field will be diffused from end faces A and B by the concentration inclination. Although the diffusion length who does thermal diffusion at the temperature of about 100 degrees C is very a minute amount, it is more desirable for the atom with a large diffusion coefficient, like an atomic radius is small to have a possibility that it may be spread directly under a ridge, and to except from alternative generally. Moreover, these atoms are excepted in order that Cu, Cr, etc. may act as a killer dopant in a nitride semi-conductor luminescence device. Especially since aluminum, B, or N is introduced as an impurity atom to introduce, and the diffusion which originates in generation of heat at the time of laser actuation by setting distance with a ridge as the range of 0.5-10 micrometers is hardly produced, either and it does not act as a nonluminescent core in a GaN system luminescence device, it is desirable.
[0025] What is necessary is just to increase the amount of atomic installation to a light absorption field to make leakage light absorb completely, since the absorption coefficient of the matter increases depending on the amount of installation of an impurity atom. The association of a crystal itself is destroyed and an impurity atom stops however, functioning as a component, since it is introduced between the crystal lattices of a semi-conductor, when the amount beyond a limit is introduced.

The amount of installation of the impurity atom which fills both the absorption of light and maintenance of a crystal is 1x1013 to 1x1017-/cm2, and its further 1x1014 to 1x1016-/cm2 is desirable.
[0026] It is the laser using the gallium nitride system compound semiconductor of laser structure as shown in drawing 1 as an example below the [example 1], and the thing in which the light absorption field further shown in drawing 2 was formed is explained.
[0027] (Substrate 101) As a substrate, by the gallium nitride system compound semiconductor and this example which were grown up into the different-species substrate, after growing up GaN with a thick film (100 micrometers), a different-species substrate is removed and the gallium nitride system compound semiconductor substrate which consists of 80-micrometer GaN is used. The detailed formation approach of a substrate is as follows. The different-species substrate which consists of sapphire which makes 2inchphi and C side a principal plane is set in a MOVPE reaction container, and temperature is made into 500 degrees C, and the buffer layer which consists of GaN is grown up by 200A thickness using trimethylgallium (TMG) and ammonia (NH3), temperature is raised after that, GaN of undoping is grown up by 1.5-micrometer thickness, and it considers as a substrate layer. Next, two or more stripe-like masks are formed in a substrate layer front face, from mask opening (window part), selective growth of the GaN is carried out in a gallium nitride system compound semiconductor and this example, the gallium nitride system compound semiconductor layer formed by the growth (ELOG) accompanied by lateral growth is further grown up with a thick film, a different-species substrate, a buffer layer, and a substrate layer are removed, and a gallium nitride system compound semiconductor substrate is obtained. At this time, the mask at the time of selective growth consists of SiO2, and let them be mask width of face of 15 micrometers, and opening (window part) width of face of 5 micrometers.
[0028] (Buffer layer 102) On a gallium nitride system compound semiconductor substrate, temperature is made into 1050 degrees C after buffer layer growth, and the buffer layer 102 which consists of aluminum0.05Ga0.95N is grown up by 4-micrometer thickness using TMG (trimethylgallium), TMA (trimethylaluminum), and ammonia. This layer functions as a buffer layer between the gallium nitride system compound semiconductor substrates which serve as n mold contact layer of AlGaN from GaN. Next, the laminating of each class used as laser structure is carried out on the substrate layer which consists of a gallium nitride system compound semiconductor.
[0029] (n mold contact layer 103) Silane gas is used as TMG, TMA, ammonia, and impurity gas on the buffer layer 102 obtained next, and n mold contact layer 103 which consists of aluminum0.05Ga0.95N which carried out Si dope at 1050 degrees C is grown up by 4-micrometer thickness.
[0030] (Crack prevention layer 104) Next, the crack prevention layer 104 which makes temperature 800 degrees C and consists of In0.06Ga0.94N is grown up by 0.15-micrometer thickness using TMG, TMI (trimethylindium), and ammonia. In addition, this crack prevention layer is omissible.
[0031] (n mold cladding layer 105) Next, the B horizon which consists of GaN

which temperature was made into 1050 degrees C, TMA, TMG, and ammonia were used for material gas, and the A horizon which consists of aluminum0.05Ga0.95N of undoping was grown up by 25A thickness, then doped Si for TMA 5x1018-/cm3, using silane gas as a stop and impurity gas is grown up by 25A thickness. And this actuation is repeated 200 times, respectively, an A horizon and a B horizon carry out a laminating, and n mold cladding layer 106 which consists of multilayers (superstructure) of the 1 micrometer of the total thickness is grown up. If it is or more 0.05 0.3 or less range as an aluminum mixed-crystal ratio of Undoping AlGaN at this time, the refractive-index difference which fully functions as a cladding layer can be established.
[0032] (n mold lightguide layer 106) Next, TMG and ammonia are used for material gas at the same temperature, and n mold lightguide layer 106 which consists of GaN of undoping is grown up by 0.15-micrometer thickness. Moreover, n mold impurity may be doped.
[0033] Temperature is made into 800 degrees C. To material gas Next, TMI (trimethylindium), (Barrier layer 107) The barrier layer (B) which consists of In0.05Ga0.95N which doped Si 5x1018-/cm3 using TMG and ammonia, using silane gas as impurity gas by 140A thickness The well layer (W) which consists silane gas of a stop and In0.1Ga0.9N of undoping is made into this barrier layer (B), and the laminating of the well layer (W) is made to the order of (B)/(W)/(B)/(W) by 55A thickness. A barrier layer 107 serves as multiplex quantum well structure (MQW) of about 500A of the total thickness.
[0034] (p mold electronic confinement layer 108) Next, TMA, TMG, and ammonia are used for material gas at the same temperature, and p mold electronic confinement layer 108 which consists of aluminum0.3Ga0.7N which doped Mg 1x1019-/cm3 is grown up by 100A thickness, using Cp2Mg (magnesium cyclopentadienyl) as impurity gas. Although especially this layer does not need to be prepared, it functions as electronic confinement by preparing, and contributes to the fall of a threshold.
[0035] (p mold lightguide layer 109) Next, temperature is made into 1050 degrees C, TMG and ammonia are used for material gas, and p mold lightguide layer 109 which consists of GaN of undoping is grown up by 0.15-micrometer thickness. Although this p mold lightguide layer 109 is grown up as undoping, by diffusion of Mg from the adjacent layer of p mold electronic confinement layer 108 and p mold cladding layer 109 grade, Mg concentration serves as 5x1016-/cm3, and it shows p mold. Moreover, this layer may dope Mg intentionally at the time of growth.
[0036] (p mold cladding layer 110) Then, the layer which consists of undoping aluminum0.05Ga0.95N at 1050 degrees C is grown up by 25A thickness, the layer which consists TMA of a Mg dope GaN using a stop and Cp2Mg continuously is grown up by 25A thickness, and p mold cladding layer 110 which repeats it 90 times and consists of a superlattice layer of the 0.45 micrometers of the total thickness is grown up. Although p mold cladding layer is in the inclination for crystallinity to become good when the gallium nitride system compound semiconductor layer from which bandgap energy differs mutually is produced by the superlattice which carried out the laminating including the gallium nitride system compound semiconductor layer in which at least one side contains

aluminum, it dopes many impurities in one of layers and the so-called modulation dope is performed, you may dope like both. A cladding layer 110 is taken as the superstructure to which considering as the gallium nitride system compound semiconductor layer containing aluminum and the superstructure which contains AlXGa1-XN (0< X<1) preferably carried out the laminating of GaN and the AlGaN desirable still more preferably. Since the refractive index of the cladding layer itself becomes small since aluminum mixed-crystal ratio of the whole cladding layer can be raised by making the p side cladding layer 110 into a superstructure, and bandgap energy becomes large further, it is very effective when reducing a threshold. Furthermore, since the pit generated in the cladding layer itself by having considered as superlattice becomes less than what is not used as superlattice, short generating also becomes low.
[0037] (p mold contact layer 111) p mold contact layer 111 which finally consists of a p mold GaN which doped Mg 1x1020-/cm3 on p mold cladding layer 110 at 1050 degrees C is grown up by 150A thickness. p mold contact layer 111 can be constituted from InXAlYGa1-X-YN (0 <=X, 0<=Y, X+Y<=1) of p mold, and GaN which doped Mg preferably, then the p electrode 120 and the most desirable ohmic contact are acquired. Since the contact layer 111 is a layer which forms an electrode, it is desirable to consider as three or more 1x1017-/cm high carrier concentration. When lower than 1x1017-/cm3, it is in the inclination it to become difficult to obtain an electrode and desirable OMIKKU. If the presentation of a contact layer is furthermore set to GaN, an electrode material and desirable OMIKKU will become is easy to be obtained. Annealing is performed for a wafer at 700 degrees C among nitrogen-gas-atmosphere mind after reaction termination and in a reaction container, and p type layer is further formed into low resistance.
[0038] After growing up a gallium nitride system compound semiconductor as mentioned above and carrying out the laminating of each class, a wafer is picked out from a reaction container, the protective coat which consists of SiO2 is formed in the front face of p mold contact layer of the maximum upper layer, and it etches by SiCl4 gas using RIE (reactive ion etching), and as shown in drawing 1 , the front face of n mold contact layer 103 which should form n electrode is exposed. Thus, for etching a gallium nitride system compound semiconductor deeply, it considers as a protective coat, and SiO2 is the optimal.
[0039] Next, a ridge stripe is formed as a waveguide field of the shape of a stripe mentioned above. First, after forming in the whole surface mostly the 1st protective coat 161 of p mold contact layer (up contact layer) of the maximum upper layer which consists of an Si oxide (mainly SiO2) by 0.5-micrometer thickness with PVD equipment, the mask of a predetermined configuration is covered on the 1st protective coat 161, and it considers as the 1st protective coat 161 with a stripe width of face of 1.6 micrometers with a photolithography technique by RIE (reactive ion etching) equipment using CF4 gas. At this time, the height (etching depth) of a ridge stripe etches a part of p mold contact layer 111 and p mold cladding layer 109, and p mold lightguide layer 110, and the thickness of p mold lightguide layer 109 etches and forms it to the depth used as 0.1 micrometers.
[0040] (Light absorption field) The mask of a resist is formed in the range

(equivalent to the surface parts of p mold cladding layer 110 and p mold lightguide layer 109 shown in drawing 2) from a ridge side face to 1 micrometer among the flat surfaces (exposure of p mold lightguide layer 109) which follow the top face, side face, and ridge side face of a ridge stripe. Next, boron ion is introduced with ion implantation equipment, and the light absorption field 1 shown in drawing 2 is formed. Ion implantation conditions set the amount of installation of boron ion (dose) to 1x1015-/cm2 for 6 minutes by acceleration voltage 30keV.
[0041] Next, the 2nd protective coat 162 which consists of a Zr oxide (mainly ZrO2) is continued and formed by 0.5-micrometer thickness from on the 1st protective coat 161 on p mold lightguide layer 109 exposed by etching the 1st protective coat 161 top.
[0042] A wafer is heat-treated at 600 degrees C after the 2nd protective coat 162 formation. Thus, since it is hard coming to dissolve the 2nd protective coat after the 2nd protective coat membrane formation by heat-treating 300 degrees C or more preferably below with the decomposition temperature (1200 degrees C) of 400 degrees C or more and a gallium nitride system compound semiconductor to the dissolution ingredient (fluoric acid) of the 1st protective coat when ingredients other than SiO2 are formed as the 2nd protective coat, it is still more desirable to add this process.
[0043] Next, a wafer is immersed in fluoric acid and the 1st protective coat 161 is removed by the lift-off method. The 1st protective coat 161 prepared on p mold contact layer 111 is removed by this, and p mold contact layer is exposed. As shown in drawing 1 as mentioned above, the 2nd protective coat 162 is formed in the side face of a ridge stripe, and the flat surface (exposure of p mold lightguide layer 109) which follows it.
[0044] Thus, after being removed, the 1st protective coat 161 prepared on p mold contact layer 112 forms the p electrode 120 which consists of nickel/Au in the front face of the exposed p mold contact layer 111, as shown in drawing 1 . However, as stripe width of face of 100 micrometers, the p electrode 120 is gone across and formed on the 2nd protective coat 162, as shown in drawing 1 . The n electrode 121 of the shape of a stripe which consists of Ti/aluminum is formed in the front face of already exposed n mold contact layer 103 in a direction parallel to a stripe after the 2nd protective coat 162 formation.
[0045] next, after forming the dielectric multilayers 164 which carry out a mask to a desired field in order to prepare an ejection electrode, and become p and n electrode from SiO2 and TiO2 in the field exposed by etching in order to form n electrode, it consists of nickel-Ti-Au (1000A-1000 A to 8000 A) on p and n electrode -- it took out (putt) and the electrode 122,123 was formed, respectively. At this time, the width of face of a barrier layer 107 is 200 micrometers in width of face (width of face of a direction perpendicular to the direction of a resonator), and the dielectric multilayers which consist of SiO2 and TiO2 are prepared also in a resonator side (reflector side).
[0046] After forming n electrode and p electrode as mentioned above, in a direction perpendicular to a stripe-like electrode, it divides in the shape of a bar by the Mth page (Mth page of GaN (1 1-0 0) etc.) of a gallium nitride system compound semiconductor, a bar-like wafer is divided further, and laser is obtained.

At this time, cavity length is 650 micrometers.
[0047] This laser component was installed in the heat sink, and when wire bonding of each pad electrode was carried out and laser oscillation was tried at the room temperature, in the oscillation wavelength of 400-420nm, and oscillation threshold-current consistency 2.9 kA/cm2, the room temperature continuous oscillation in single transverse mode was shown. Moreover, when FFP was measured, it became like drawing 3 , generating of a ripple was controlled sharply, and horizontal optical intensity distribution were smooth intensity distribution. The strong peak location was also mostly in agreement with the center position of FFP.
[0048] The gallium nitride system semiconducting compound laser which changed the amount of installation of the impurity atom (boron) in the [example 2] example 1 into 1x1014-/cm2, and formed the light absorption field was created, and it oscillated on an example 1 and these conditions. When FFP is measured, although some ripple has appeared like drawing 4 , as for horizontal optical intensity distribution, it turns out that the ripple is sharply restricted compared with the example of a comparison (drawing 6).
[0049] The gallium nitride system semiconducting compound laser which changed the amount of installation of the impurity atom (boron) in the [example 3] example 1 into 1x1016-/cm2, and formed the light absorption field was created, and it oscillated on the same conditions as an example 1. When FFP is measured, although some ripple has appeared like drawing 5 , as for horizontal optical intensity distribution, it turns out that the ripple is sharply restricted compared with the example of a comparison (drawing 6).
[0050] The gallium nitride system semiconducting compound laser in the [example of comparison] example 1 thru/or 3 which removes like the formation fault of a light absorption field, and does not have a light absorption field was created, and it oscillated on the same conditions as an example 1. When FFP was measured, it was checked that the ripple has occurred in large quantities so that horizontal optical intensity distribution might be drawing 6 . As compared with drawing 3 thru/or 5, it turned out that the peak location has shifted from the peak location of original FFP smoothly [the configuration of optical intensity distribution].
[0051]
[Effect of the Invention] When the gallium nitride system compound semiconductor laser of this invention has the structure of having a light absorption field in a part of lightguide, the level transverse-mode control which is the fault of ridge guided wave mold stripe geometry is strengthened. Consequently, the ripple of FFP which had appeared in the conventional gallium nitride system compound semiconductor laser was eliminated efficiently. Consequently, the horizontal intensity distribution of FFP become smooth by removal of a ripple, and the peak location comes to be in agreement with the core of FFP, and it becomes possible to condense a laser spot with a sufficient precision by this.

[Translation done.]

TECHNICAL FIELD

[Field of the Invention] This invention relates to gallium nitride system semiconducting compound laser.

[Translation done.]

PRIOR ART

[Description of the Prior Art] The demand to use to the optical disc system which the semiconductor laser using a nitride semi-conductor can reproduce [information record and] is high today. [of large capacity, such as DVD, and high density] It is considered by especially the next generation DVD treating digital image data for the short paddle blue laser of wavelength to be indispensable. As blue semiconductor laser, gallium nitride system semiconducting compound laser is the most leading.
[0003] The laser spot used for data reading and the writing of an optical disk, for example, DVD, needs to be condensed by pinpoint, and, for that purpose, the center position of a far field pattern (a far field pattern, FFP) needs to become clear. Moreover, as for the perpendicular direction of FFP, and horizontal intensity distribution, it is desirable that it is Gaussian distribution. The condition of these intensity distribution can be called transverse mode, and it can control by structure of semiconductor laser.
[0004] The typical structure of semiconductor laser is the double heterojunction structure (DH structure) which put the barrier layer by p mold and n mold cladding layer. DH structure aims at the carrier locked-in effect to a barrier layer, and the locked-in effect of the light of a laminating perpendicular direction. The SCH structure where the lightguide layer is formed between [each] the barrier layer, p mold, and n mold cladding layer is in a kind of DH structure, and light is confined in the lightguide which consists of three layers of a barrier layer and a lightguide layer with this configuration. Thus, the transverse mode (perpendicular transverse mode) of the laminating perpendicular direction of light is controllable by SCH structure.
[0005] Stripe geometry is used in order to also control the transverse mode (level transverse mode) of a laminating horizontal direction further in addition to the perpendicular transverse mode of light. Stripe geometry is divided roughly into gain guided wave mold stripe geometry and refractive-index guided wave mold stripe geometry. Light is confined in the directly under field of a ridge by the difference of the effectual refractive index of the directly under field of a ridge, and the other field (the field outside a ridge is called) in inside, and the level transverse mode of light has the ridge guided wave mold stripe geometry controlled.

[Translation done.]

EFFECT OF THE INVENTION

[Effect of the Invention] When the gallium nitride system compound semiconductor laser of this invention has the structure of having a light absorption field in a part of lightguide, the level transverse-mode control which is the fault of ridge guided wave mold stripe geometry is strengthened. Consequently, the ripple of FFP which had appeared in the conventional gallium nitride system compound semiconductor laser was eliminated efficiently. Consequently, the horizontal intensity distribution of FFP become smooth by removal of a ripple, and the peak location comes to be in agreement with the core of FFP, and it becomes possible to condense a laser spot with a sufficient precision by this.

[Translation done.]

TECHNICAL PROBLEM

[Problem(s) to be Solved by the Invention] However, in fact, the optical confinement in said ridge guided wave mold stripe geometry is not perfect, and the light of a minute amount is beginning to leak from the directly under field of a ridge to the field outside a ridge. The light (leakage light) which began to leak from the directly under field of a ridge is emitted with the laser beam to oscillate, and appears as a noise (ripple) in FFP. By this ripple of FFP, trouble is caused to condensing of a laser spot and it becomes the cause of the read-out and the write error of optical disc systems, such as DVD. Then, this invention aims at obtaining the laser in which FFP without a ripple is shown.

[Translation done.]

MEANS

[Means for Solving the Problem] In order to solve a technical problem, this invention has the laminated structure which sandwiched the barrier layer which consists of a gallium nitride system compound semiconductor in p mold gallium nitride system compound semiconductor layer and n mold gallium nitride system compound semiconductor layer. In the gallium nitride system compound semiconductor laser with which p mold gallium nitride system compound semiconductor layer is partially removed, and the ridge is formed It is characterized by forming the light absorption field which estranges in p mold gallium nitride system semi-conductor layer of said ridge both sides from the directly under field of said ridge, introduces the impurity atom except Cu and Cr into it, and grows into it. No matter what atom [impurity] it may introduce, since an absorption-of-light multiplier rises, especially the class of impurity atom to introduce is not limited, but if spread to the carrier recombination field in a luminous layer, since ****** and luminescence reinforcement will fall as a nonluminescent recombination center, neither Cu nor Cr is desirable. Moreover, since the diffusion coefficient in the inside of the gallium nitride system compound semiconductor of the impurity atom to introduce may move too that it is a large atom to the directly under field of a ridge after installation and may check luminescence, it is desirable to introduce an atom with the small diffusion coefficient of the small atom of an atomic radius etc. Still more preferably, mobility introduces the impurity atom of either of low B, aluminum, and N, and forms a light absorption field.
[0008] In this invention, two conditions are mentioned at worst about the location which forms a light absorption field. The first condition of the location which forms a light absorption field is removing the directly under field of a ridge. The directly under field of a ridge is a guided wave field of light, and forming an absorption field there becomes the cause of reducing the luminous efficiency of laser. Next, it becomes conditions that a light absorption field does not touch the directly under field of a ridge. After introducing an impurity atom, even if it is predicted by thermal diffusion that an impurity atom is spread and expansion of a light absorption field breaks out as the result by it, it is for making it not trespass upon the directly under field of a ridge.
[0009] Moreover, forming a light absorption field in the location which does not touch the directly under field of a ridge is based also on the reason explained

below. Ridge guided wave mold structure has the description that the effectual refractive indexes of the directly under field of a ridge and the field outside a ridge differ, and when light reflects in the interface of the refractive index, it controls the level transverse mode. Installation of an impurity atom must be careful also of the effectiveness of changing a refractive index for an impurity atom not to trespass upon the refractive-index interface of ridge structure from a certain thing. Therefore, in consideration of migration of the impurity atom by thermal diffusion, it is necessary to form a light absorption field in the location distant from ridge both ends. Moreover, in order for the function of the leakage absorption of light to work effectively, the distance of a ridge and a light absorption field must not separate too much. The clearance for which are suitable is set to 0.5-10 micrometers from atomic thermal diffusion and the balance of the light absorption effectiveness, and it is 1-5 micrometers still more preferably.

[0010] It is desirable to introduce an impurity atom by the ion implantation which is excellent in this invention at control of the impurity atom installation location of the depth direction, control of the amount of impurity atom installation, and mass-production nature although what kind of approach may be used for installation of an impurity atom. Moreover, since it generates in a lightguide, as for leakage light, it is desirable to locate the peak of concentration distribution of the impurity atom in the depth direction in a lightguide. A lightguide points out the set of all the layers pinched by p mold and n mold cladding layer, and this means the layer in which light mainly closes and eye ** is performed here. Between p mold and n mold cladding layer, since the lightguide layer, the electronic confining layer, etc. are formed other than the barrier layer, it is considered that those layers are a part of lightguides.

[0011] In the light absorption field used by this invention, an absorption coefficient increases by enlarging the consistency of an impurity atom. When there are too many amounts of installation, the crystal lattice itself is destroyed and it stops however, functioning as a laser component. In order to realize the leakage absorption-of-light function which is the purpose of this invention, maintaining the crystal structure, the amount of the impurity atom to introduce is 1x1014 to 1x1016-/cm2 preferably that what is necessary is just to be in the range of 1x1013 to 1x1017-/cm2.

[0012]

[Embodiment of the Invention] As a gallium nitride system compound semiconductor used for the gallium nitride system compound semiconductor laser of this invention, there is a gallium nitride system compound semiconductor (InxAlyGa1-x-yN, 0<=x, 0<=y, x+y<=1) which are GaN, AlN, InN(s), or such mixed crystal. In addition, the mixed crystal which permuted said some of gallium nitride system compound semiconductors by B and P is sufficient.

[0013] Drawing 1 is the sectional view showing an example of the gallium nitride system compound semiconductor laser concerning this invention. The barrier layer 107 which consists of InxGa1-xN (0<=x<1) on the GaN substrate 101 is sandwiched by the n mold AlyGa1-yN (0<=y<1) layers 103-106 (the values of y differ for each class), and the p mold AlzGa1-zN (0<=z<1) layers 108-111 (the values of z differ for each class), and terrorism structure is formed in the so-called

double.

[0014] Drawing 2 extracts and illustrates the part about formation of a light absorption field among the laminated structures of the semiconductor laser shown in drawing 1 . After the light absorption field 1 carries out the laminating of the lightguide layer 109 and the cladding layer 110 one by one and subsequently forms a ridge stripe, it introduces an impurity atom into the position of p mold lightguide layer which became unreserved, and is formed in it. As for aperture-width w' of a light absorption field, and the relation with the ridge width of face w, it is desirable to make it w'>=w+1micrometer. Moreover, the end face A of a light absorption field, the end face C of the directly under field of a ridge, and the end face B of a light absorption field and the end face D of the directly under field of a ridge leave respectively only 0.5-10 micrometers of locations which form the light absorption field 1, and leaves them only 1-5 micrometers respectively still more preferably. Moreover, although it is desirable that it is bilateral symmetry as for the physical relationship of two end faces A and B of the light absorption field centering on a ridge, it may not be bilateral symmetry.

[0015] Hereafter, the detail of structure is explained about the gallium nitride system compound semiconductor laser shown in drawing 1 . Although it is desirable as a substrate 101 to use GaN, a different different-species substrate from a gallium nitride system compound semiconductor may be used. The sapphire which makes a principal plane either C side, the Rth page and the Ath page as a different-species substrate, for example, Spinel (an insulating substrate like MgA 12O4, SiC (4H 6H)) ZnS, ZnO, GaAs and Si containing 3C, the oxide substrate which carries out lattice matching to a gallium nitride system compound semiconductor can grow up a gallium nitride system compound semiconductor, and is known from the former, and a different substrate ingredient from a gallium nitride system compound semiconductor can be used. Sapphire and a spinel are mentioned as a desirable different-species substrate. Moreover, a different-species substrate is desirable in order that the substrate layer which consists of gallium nitride may grow with sufficient crystallinity, if what may be carrying out the off angle type and carried out the off angle type to the shape of a step in this case is used. Furthermore, the approach of removing a different-species substrate by approaches, such as polish, forming laser structure as a simple substance substrate of a gallium nitride system compound semiconductor after growing up the gallium nitride system compound semiconductor used as the substrate layer before laser structure formation on a different-species substrate, in using a different-species substrate, and removing a different-species substrate after laser structure formation may be used.

[0016] If it forms laser structure through a buffer layer (low-temperature growth phase) and the substrate layer which consists of a gallium nitride system compound semiconductor (preferably GaN) in using a different-species substrate, growth of a gallium nitride system compound semiconductor will become good. Moreover, if the gallium nitride system compound semiconductor which used as the substrate layer (growth substrate) prepared on a different-species substrate, in addition carried out ELOG (Epitaxially Laterally Overgrowth) growth is used, a growth substrate with good crystallinity will be obtained. The mask field where the

gallium nitride system compound semiconductor layer was grown up, and growth of a gallium nitride system compound semiconductor prepared and formed the difficult protective coat on the front face on the different-species substrate as an example of an ELOG growth phase, By preparing the non-mask field into which a gallium nitride system compound semiconductor is grown up in the shape of a stripe, and growing up a gallium nitride system compound semiconductor from the non-mask field In addition to growth in the direction of thickness, when growth in a longitudinal direction accomplishes, there is a layer in which the gallium nitride system compound semiconductor grew up to be also a mask field, and was formed. The layer which opening is prepared in the gallium nitride system compound semiconductor layer grown up on the different-species substrate with other gestalten, and the growth in a longitudinal direction from the opening side face is made, and is formed is sufficient.

[0017] On the substrate 101, n mold contact layer 103 which is n mold gallium nitride system compound semiconductor layer, the crack prevention layer 104, n mold cladding layer 105, and n mold lightguide layer 106 are formed through the buffer layer 102. Other layers except n mold cladding layer 105 are also omissible depending on laser. n mold gallium nitride system compound semiconductor layer needs to have a band gap larger than a barrier layer in the part which touches a barrier layer at least, therefore it is desirable that it is the presentation containing aluminum. Moreover, it is made to grow up, doping n mold impurity, and is good also as an n mold, and each class is grown up by undoping and is good also as an n mold.

[0018] The barrier layer 107 is formed on n mold gallium nitride system compound semiconductor layers 103-106. The barrier layer 107 has the MQW structure where the laminating only of the count with suitable Inx1Ga1-x2N well layer (0<x1<1) and Inx2Ga1-x2N barrier layer (0 <=x2<1, x1> x2) was carried out repeatedly by turns, as above-mentioned, and each both ends of a barrier layer serve as a barrier layer. The well layer is formed by undoping, n mold impurities, such as Si and Sn, dope all barrier layers preferably by the concentration of 1x1017 to 1x1019-/cm3, and they are formed.

[0019] On the last barrier layer, p mold electronic confining layer 108, p mold lightguide layer 109, p mold cladding layer 110, and p mold contact layer 111 are formed as a p mold gallium nitride system compound semiconductor layer. Other layers except p mold cladding layer 110 are also omissible depending on laser. p mold gallium nitride system compound semiconductor layer needs to have a band gap larger than a barrier layer in the part which touches a barrier layer at least, therefore it is desirable that it is the presentation containing aluminum. Moreover, it is made to grow up, doping p mold impurity, and is good also as a p mold, and each class diffuses p mold impurity from other adjoining layers, and is good also as a p mold.

[0020] from p mold gallium nitride system compound semiconductor in which p mold electronic confining layer 108 has aluminum mixed-crystal ratio higher than p mold cladding layer 110 -- changing -- desirable -- AlxGa1-xN (0.1< x<0.5) -- it has a presentation. Moreover, p mold impurities, such as Mg, are preferably doped by high concentration by the concentration of 5x1017 to 1x1019-/cm3. Thereby, p

mold electronic confining layer 108 can shut up an electron effectively in a barrier layer, and reduces the threshold of laser.
[0021] A ridge stripe is formed to the middle of p mold lightguide layer 109 among p mold gallium nitride system compound semiconductor layers, further, protective coats 161 and 162, p mold electrode 120, n mold electrode 121, p putt electrode 122, and n putt electrode 123 are formed, and semiconductor laser is constituted.
[0022] Although a light absorption field is formed of installation of an impurity atom, thermal diffusion, ion implantation, etc. are mentioned as the approach. However, in the case of thermal diffusion, at temperature lower than the temperature (about 1000 degrees C) which the crystal of a nitriding gallium compound semi-conductor decomposes, an atom must be spread in a lightguide and the impurity atom which can be chosen is limited. On the other hand, if an impurity atom is introduced by ion implantation, even if it uses what kind of atom, a semi-conductor does not amount to 1000 degrees C, and an impurity atom can choose freely.
[0023] Other advantages of ion implantation are adjusting acceleration voltage, and are being able to choose the introductory depth of an impurity atom. When thermal diffusion is used, concentration becomes low as concentration distribution of an impurity atom is high concentration most and a front face becomes deep. However, if ion implantation is used, formation of concentration distribution for which a concentration peak comes to the depth location of the request inside a crystal is also possible. In this invention, if it is desirable for the concentration peak of an impurity atom to be in the photoconductive wave member which leakage light generates and this uses ion implantation, it is realizable.
[0024] The impurity atom to introduce is chosen by the diffusion coefficient in the gallium nitride semiconducting compound crystal of the atom. Generally, among laser oscillation, although a component generates heat and temperature rises, the atom introduced into the light absorption field will be diffused from end faces A and B by the concentration inclination. Although the diffusion length who does thermal diffusion at the temperature of about 100 degrees C is very a minute amount, it is more desirable for the atom with a large diffusion coefficient, like an atomic radius is small to have a possibility that it may be spread directly under a ridge, and to except from alternative generally. Moreover, these atoms are excepted in order that Cu, Cr, etc. may act as a killer dopant in a nitride semi-conductor luminescence device. Especially since aluminum, B, or N is introduced as an impurity atom to introduce, and the diffusion which originates in generation of heat at the time of laser actuation by setting distance with a ridge as the range of 0.5-10 micrometers is hardly produced, either and it does not act as a nonluminescent core in a GaN system luminescence device, it is desirable.
[0025] What is necessary is just to increase the amount of atomic installation to a light absorption field to make leakage light absorb completely, since the absorption coefficient of the matter increases depending on the amount of installation of an impurity atom. The association of a crystal itself is destroyed and an impurity atom stops however, functioning as a component, since it is introduced between the crystal lattices of a semi-conductor, when the amount beyond a limit is introduced. The amount of installation of the impurity atom which fills both the absorption of

light and maintenance of a crystal is 1x1013 to 1x1017-/cm2, and its further 1x1014 to 1x1016-/cm2 is desirable.
[0026] It is the laser using the gallium nitride system compound semiconductor of laser structure as shown in drawing 1 as an example below the [example 1], and the thing in which the light absorption field further shown in drawing 2 was formed is explained.
[0027] (Substrate 101) As a substrate, by the gallium nitride system compound semiconductor and this example which were grown up into the different-species substrate, after growing up GaN with a thick film (100 micrometers), a different-species substrate is removed and the gallium nitride system compound semiconductor substrate which consists of 80-micrometer GaN is used. The detailed formation approach of a substrate is as follows. The different-species substrate which consists of sapphire which makes 2inchphi and C side a principal plane is set in a MOVPE reaction container, and temperature is made into 500 degrees C, and the buffer layer which consists of GaN is grown up by 200A thickness using trimethylgallium (TMG) and ammonia (NH3), temperature is raised after that, GaN of undoping is grown up by 1.5-micrometer thickness, and it considers as a substrate layer. Next, two or more stripe-like masks are formed in a substrate layer front face, from mask opening (window part), selective growth of the GaN is carried out in a gallium nitride system compound semiconductor and this example, the gallium nitride system compound semiconductor layer formed by the growth (ELOG) accompanied by lateral growth is further grown up with a thick film, a different-species substrate, a buffer layer, and a substrate layer are removed, and a gallium nitride system compound semiconductor substrate is obtained. At this time, the mask at the time of selective growth consists of SiO2, and let them be mask width of face of 15 micrometers, and opening (window part) width of face of 5 micrometers.
[0028] (Buffer layer 102) On a gallium nitride system compound semiconductor substrate, temperature is made into 1050 degrees C after buffer layer growth, and the buffer layer 102 which consists of aluminum0.05Ga0.95N is grown up by 4-micrometer thickness using TMG (trimethylgallium), TMA (trimethylaluminum), and ammonia. This layer functions as a buffer layer between the gallium nitride system compound semiconductor substrates which serve as n mold contact layer of AlGaN from GaN. Next, the laminating of each class used as laser structure is carried out on the substrate layer which consists of a gallium nitride system compound semiconductor.
[0029] (n mold contact layer 103) Silane gas is used as TMG, TMA, ammonia, and impurity gas on the buffer layer 102 obtained next, and n mold contact layer 103 which consists of aluminum0.05Ga0.95N which carried out Si dope at 1050 degrees C is grown up by 4-micrometer thickness.
[0030] (Crack prevention layer 104) Next, the crack prevention layer 104 which makes temperature 800 degrees C and consists of In0.06Ga0.94N is grown up by 0.15-micrometer thickness using TMG, TMI (trimethylindium), and ammonia. In addition, this crack prevention layer is omissible.
[0031] (n mold cladding layer 105) Next, the B horizon which consists of GaN which temperature was made into 1050 degrees C, TMA, TMG, and ammonia were

used for material gas, and the A horizon which consists of aluminum0.05Ga0.95N of undoping was grown up by 25A thickness, then doped Si for TMA 5x1018-/cm3, using silane gas as a stop and impurity gas is grown up by 25A thickness. And this actuation is repeated 200 times, respectively, an A horizon and a B horizon carry out a laminating, and n mold cladding layer 106 which consists of multilayers (superstructure) of the 1 micrometer of the total thickness is grown up. If it is or more 0.05 0.3 or less range as an aluminum mixed-crystal ratio of Undoping AlGaN at this time, the refractive-index difference which fully functions as a cladding layer can be established.
[0032] (n mold lightguide layer 106) Next, TMG and ammonia are used for material gas at the same temperature, and n mold lightguide layer 106 which consists of GaN of undoping is grown up by 0.15-micrometer thickness. Moreover, n mold impurity may be doped.
[0033] Temperature is made into 800 degrees C. To material gas Next, TMI (trimethylindium), (Barrier layer 107) The barrier layer (B) which consists of In0.05Ga0.95N which doped Si 5x1018-/cm3 using TMG and ammonia, using silane gas as impurity gas by 140A thickness The well layer (W) which consists silane gas of a stop and In0.1Ga0.9N of undoping is made into this barrier layer (B), and the laminating of the well layer (W) is made to the order of (B)/(W)/(B)/(W) by 55A thickness. A barrier layer 107 serves as multiplex quantum well structure (MQW) of about 500A of the total thickness.
[0034] (p mold electronic confinement layer 108) Next, TMA, TMG, and ammonia are used for material gas at the same temperature, and p mold electronic confinement layer 108 which consists of aluminum0.3Ga0.7N which doped Mg 1x1019-/cm3 is grown up by 100A thickness, using Cp2Mg (magnesium cyclopentadienyl) as impurity gas. Although especially this layer does not need to be prepared, it functions as electronic confinement by preparing, and contributes to the fall of a threshold.
[0035] (p mold lightguide layer 109) Next, temperature is made into 1050 degrees C, TMG and ammonia are used for material gas, and p mold lightguide layer 109 which consists of GaN of undoping is grown up by 0.15-micrometer thickness. Although this p mold lightguide layer 109 is grown up as undoping, by diffusion of Mg from the adjacent layer of p mold electronic confinement layer 108 and p mold cladding layer 109 grade, Mg concentration serves as 5x1016-/cm3, and it shows p mold. Moreover, this layer may dope Mg intentionally at the time of growth.
[0036] (p mold cladding layer 110) Then, the layer which consists of undoping aluminum0.05Ga0.95N at 1050 degrees C is grown up by 25A thickness, the layer which consists TMA of a Mg dope GaN using a stop and Cp2Mg continuously is grown up by 25A thickness, and p mold cladding layer 110 which repeats it 90 times and consists of a superlattice layer of the 0.45 micrometers of the total thickness is grown up. Although p mold cladding layer is in the inclination for crystallinity to become good when the gallium nitride system compound semiconductor layer from which bandgap energy differs mutually is produced by the superlattice which carried out the laminating including the gallium nitride system compound semiconductor layer in which at least one side contains aluminum, it dopes many impurities in one of layers and the so-called modulation

dope is performed, you may dope like both. A cladding layer 110 is taken as the superstructure to which considering as the gallium nitride system compound semiconductor layer containing aluminum and the superstructure which contains AlXGa1-XN (0< X<1) preferably carried out the laminating of GaN and the AlGaN desirable still more preferably. Since the refractive index of the cladding layer itself becomes small since aluminum mixed-crystal ratio of the whole cladding layer can be raised by making the p side cladding layer 110 into a superstructure, and bandgap energy becomes large further, it is very effective when reducing a threshold. Furthermore, since the pit generated in the cladding layer itself by having considered as superlattice becomes less than what is not used as superlattice, short generating also becomes low.

[0037] (p mold contact layer 111) p mold contact layer 111 which finally consists of a p mold GaN which doped Mg 1x1020-/cm3 on p mold cladding layer 110 at 1050 degrees C is grown up by 150A thickness. p mold contact layer 111 can be constituted from InXAlYGa1-X-YN (0 <=X, 0<=Y, X+Y<=1) of p mold, and GaN which doped Mg preferably, then the p electrode 120 and the most desirable ohmic contact are acquired. Since the contact layer 111 is a layer which forms an electrode, it is desirable to consider as three or more 1x1017-/cm high carrier concentration. When lower than 1x1017-/cm3, it is in the inclination it to become difficult to obtain an electrode and desirable OMIKKU. If the presentation of a contact layer is furthermore set to GaN, an electrode material and desirable OMIKKU will become is easy to be obtained. Annealing is performed for a wafer at 700 degrees C among nitrogen-gas-atmosphere mind after reaction termination and in a reaction container, and p type layer is further formed into low resistance.

[0038] After growing up a gallium nitride system compound semiconductor as mentioned above and carrying out the laminating of each class, a wafer is picked out from a reaction container, the protective coat which consists of SiO2 is formed in the front face of p mold contact layer of the maximum upper layer, and it etches by SiCl4 gas using RIE (reactive ion etching), and as shown in drawing 1 , the front face of n mold contact layer 103 which should form n electrode is exposed. Thus, for etching a gallium nitride system compound semiconductor deeply, it considers as a protective coat, and SiO2 is the optimal.

[0039] Next, a ridge stripe is formed as a waveguide field of the shape of a stripe mentioned above. First, after forming in the whole surface mostly the 1st protective coat 161 of p mold contact layer (up contact layer) of the maximum upper layer which consists of an Si oxide (mainly SiO2) by 0.5-micrometer thickness with PVD equipment, the mask of a predetermined configuration is covered on the 1st protective coat 161, and it considers as the 1st protective coat 161 with a stripe width of face of 1.6 micrometers with a photolithography technique by RIE (reactive ion etching) equipment using CF4 gas. At this time, the height (etching depth) of a ridge stripe etches a part of p mold contact layer 111 and p mold cladding layer 109, and p mold lightguide layer 110, and the thickness of p mold lightguide layer 109 etches and forms it to the depth used as 0.1 micrometers.

[0040] (Light absorption field) The mask of a resist is formed in the range (equivalent to the surface parts of p mold cladding layer 110 and p mold lightguide

layer 109 shown in drawing 2) from a ridge side face to 1 micrometer among the flat surfaces (exposure of p mold lightguide layer 109) which follow the top face, side face, and ridge side face of a ridge stripe. Next, boron ion is introduced with ion implantation equipment, and the light absorption field 1 shown in drawing 2 is formed. Ion implantation conditions set the amount of installation of boron ion (dose) to 1x1015-/cm2 for 6 minutes by acceleration voltage 30keV.
[0041] Next, the 2nd protective coat 162 which consists of a Zr oxide (mainly ZrO2) is continued and formed by 0.5-micrometer thickness from on the 1st protective coat 161 on p mold lightguide layer 109 exposed by etching the 1st protective coat 161 top.
[0042] A wafer is heat-treated at 600 degrees C after the 2nd protective coat 162 formation. Thus, since it is hard coming to dissolve the 2nd protective coat after the 2nd protective coat membrane formation by heat-treating 300 degrees C or more preferably below with the decomposition temperature (1200 degrees C) of 400 degrees C or more and a gallium nitride system compound semiconductor to the dissolution ingredient (fluoric acid) of the 1st protective coat when ingredients other than SiO2 are formed as the 2nd protective coat, it is still more desirable to add this process.
[0043] Next, a wafer is immersed in fluoric acid and the 1st protective coat 161 is removed by the lift-off method. The 1st protective coat 161 prepared on p mold contact layer 111 is removed by this, and p mold contact layer is exposed. As shown in drawing 1 as mentioned above, the 2nd protective coat 162 is formed in the side face of a ridge stripe, and the flat surface (exposure of p mold lightguide layer 109) which follows it.
[0044] Thus, after being removed, the 1st protective coat 161 prepared on p mold contact layer 112 forms the p electrode 120 which consists of nickel/Au in the front face of the exposed p mold contact layer 111, as shown in drawing 1 . However, as stripe width of face of 100 micrometers, the p electrode 120 is gone across and formed on the 2nd protective coat 162, as shown in drawing 1 . The n electrode 121 of the shape of a stripe which consists of Ti/aluminum is formed in the front face of already exposed n mold contact layer 103 in a direction parallel to a stripe after the 2nd protective coat 162 formation.
[0045] next, after forming the dielectric multilayers 164 which carry out a mask to a desired field in order to prepare an ejection electrode, and become p and n electrode from SiO2 and TiO2 in the field exposed by etching in order to form n electrode, it consists of nickel-Ti-Au (1000A-1000 A to 8000 A) on p and n electrode -- it took out (putt) and the electrode 122,123 was formed, respectively. At this time, the width of face of a barrier layer 107 is 200 micrometers in width of face (width of face of a direction perpendicular to the direction of a resonator), and the dielectric multilayers which consist of SiO2 and TiO2 are prepared also in a resonator side (reflector side).
[0046] After forming n electrode and p electrode as mentioned above, in a direction perpendicular to a stripe-like electrode, it divides in the shape of a bar by the Mth page (Mth page of GaN (1 1-0 0) etc.) of a gallium nitride system compound semiconductor, a bar-like wafer is divided further, and laser is obtained. At this time, cavity length is 650 micrometers.

[0047] This laser component was installed in the heat sink, and when wire bonding of each pad electrode was carried out and laser oscillation was tried at the room temperature, in the oscillation wavelength of 400-420nm, and oscillation threshold-current consistency 2.9 kA/cm2, the room temperature continuous oscillation in single transverse mode was shown. Moreover, when FFP was measured, it became like drawing 3 , generating of a ripple was controlled sharply, and horizontal optical intensity distribution were smooth intensity distribution. The strong peak location was also mostly in agreement with the center position of FFP.
[0048] The gallium nitride system semiconducting compound laser which changed the amount of installation of the impurity atom (boron) in the [example 2] example 1 into 1x1014-/cm2, and formed the light absorption field was created, and it oscillated on an example 1 and these conditions. When FFP is measured, although some ripple has appeared like drawing 4 , as for horizontal optical intensity distribution, it turns out that the ripple is sharply restricted compared with the example of a comparison (drawing 6).
[0049] The gallium nitride system semiconducting compound laser which changed the amount of installation of the impurity atom (boron) in the [example 3] example 1 into 1x1016-/cm2, and formed the light absorption field was created, and it oscillated on the same conditions as an example 1. When FFP is measured, although some ripple has appeared like drawing 5 , as for horizontal optical intensity distribution, it turns out that the ripple is sharply restricted compared with the example of a comparison (drawing 6).
[0050] The gallium nitride system semiconducting compound laser in the [example of comparison] example 1 thru/or 3 which removes like the formation fault of a light absorption field, and does not have a light absorption field was created, and it oscillated on the same conditions as an example 1. When FFP was measured, it was checked that the ripple has occurred in large quantities so that horizontal optical intensity distribution might be drawing 6 . As compared with drawing 3 thru/or 5, it turned out that the peak location has shifted from the peak location of original FFP smoothly [the configuration of optical intensity distribution].

[Translation done.]

DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]
[Drawing 1] It is the type section Fig. of the semiconductor laser explaining the operation gestalt of this invention.
[Drawing 2] It is drawing which extracted the configuration around the light absorption field of it among the operation gestalten of this invention.
[Drawing 3] They are the intensity distribution of FFP of the laser of an example 1 which can be set horizontally.
[Drawing 4] They are the intensity distribution of FFP of the laser of an example 2 which can be set horizontally.
[Drawing 5] They are the intensity distribution of FFP of the laser of an example 3 which can be set horizontally.
[Drawing 6] They are the intensity distribution of FFP of the laser of the example of a comparison which can be set horizontally.
[Brief Description of Notations]
1 ... Light absorption layer
w ... Ridge width of face
w' ... Aperture width of a light absorption field
A ... End face of a light absorption field
B ... End face of a light absorption field
C ... End face of the directly under field of a ridge
D ... End face of the directly under field of a ridge
101 ... Substrate (GaN substrate)
102 ... Buffer layer
103 ... n mold contact layer
104 ... Crack prevention layer
105 ... n mold cladding layer
106 ... n mold lightguide layer
107 ... Barrier layer
108 ... p mold electronic confinement layer
109 ... p mold lightguide layer
110 ... p mold cladding layer
111 ... p mold contact layer
120 ... p electrode
121 ... n electrode

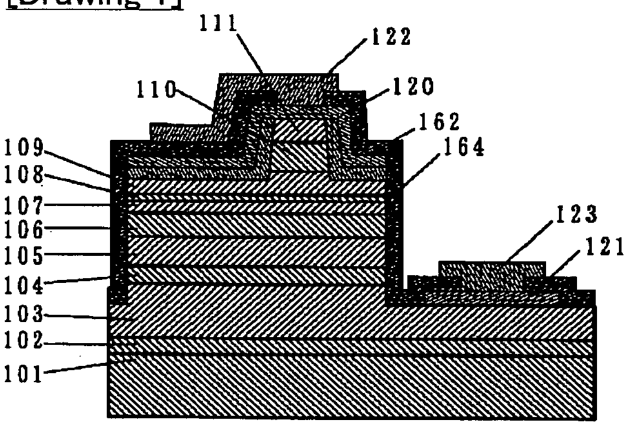
122 ... p pad electrode
123 ... n pad electrode
163 ... The 3rd protective coat
164 ... Insulator layer

[Translation done.]

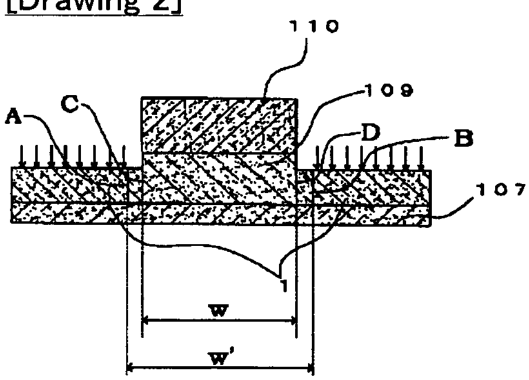
* NOTICES *

DRAWINGS

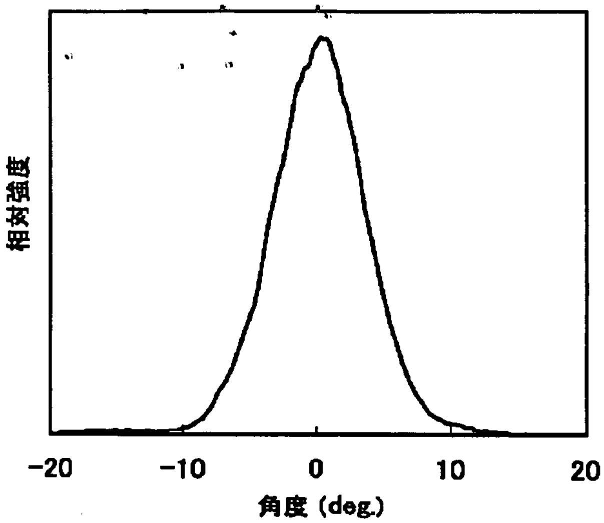
[Drawing 1]



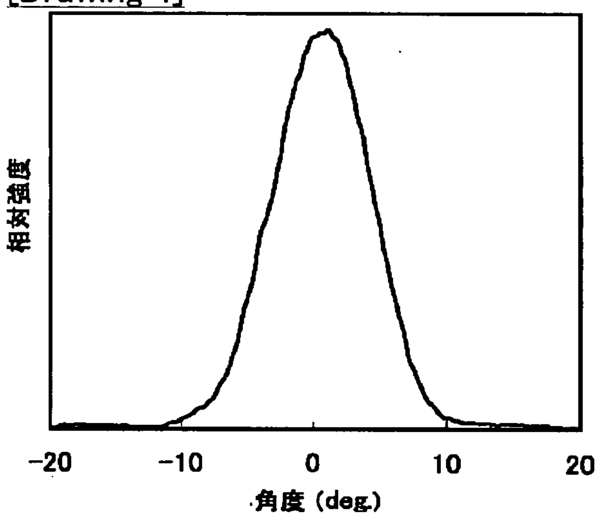
[Drawing 2]



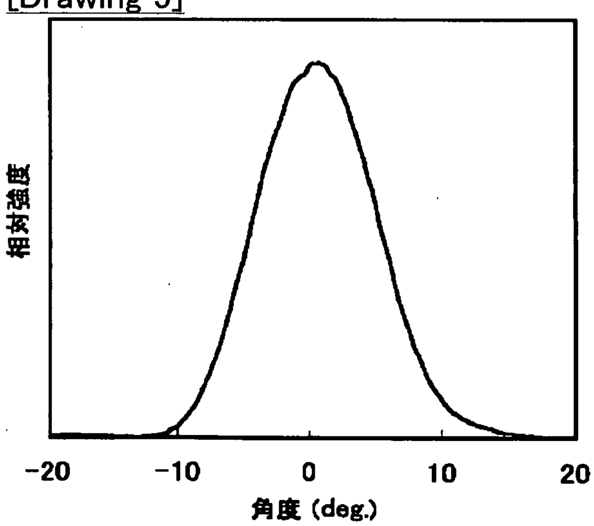
[Drawing 3]



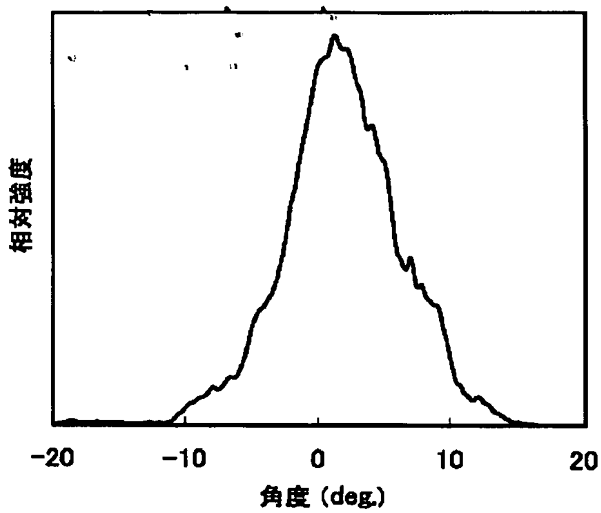
[Drawing 4]



[Drawing 5]



[Drawing 6]



[Translation done.]